DOCUMENT RESUME

ED 288 700 SE 048 712

AUTHOR Anderson, Charles W.; And Others
TITLE Power Cell: Teacher's Guide to Respiration. Occasional Paper No. 113.
INSTITUTION Michigan State Univ., East Lansing. Inst. for Research on Teaching.
PUB DATE Nov 87
NOTE 114p.
AVAILABLE FROM Institute for Research on Teaching, College of Education, Michigan State University, 252 Erickson Hall, East Lansing, MI 48824 ($11.25).
PUB TYPE Guides - Classroom Use - Guides (For Teachers) (052)

EDRS PRICE MF01/PC05 Plus Postage.
DESCRIPTORS Biology; Concept Formation; *Cytology; Experiential Learning; Junior High Schools; Laboratory Procedures; Middle Schools; Misconceptions; *Science Activities; Science Curriculum; Science Education; *Science Experiments; *Science Instruction; *Secondary School Science; *Teaching Methods
IDENTIFIERS *Respiration

ABSTRACT

This document contains a set of instructional materials about cellular respiration that were used in a research study of middle school science teaching during 1985-86. The Middle School Science Project investigated ways to help middle school science teachers use teaching strategies that were identified in earlier studies as particularly effective in promoting meaningful conceptual-change learning. Such learning requires students to go beyond memorization of facts and terminology and to make sense of scientific explanations of phenomena. For students, such learning in science often requires them to go through a difficult process of conceptual change, reshaping and abandoning ideas or misconceptions that they have developed from experience and have believed for a long time. The materials include an introductory description of students' difficulties related to learning about photosynthesis, a student text with accompanying comments and suggestions to teachers, a set of overhead transparent masters, and suggested laboratory and demonstration activities. (Author/TW)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

- This document has been reproduced as received from the person or organization originating it.
- ☐ Minor changes have been made to improve reproduction quality.
- Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

Occasional Paper No. 113

POWER CELL: TEACHER'S GUIDE TO RESPIRATION

Charles W. Anderson, Kathleen J. Roth, Robert Hollon, and Theron Blakeslee

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Charles W. Anderson
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Occasional Paper No. 113

POWER CELL: TEACHER'S GUIDE TO RESPIRATION

Charles W. Anderson, Kathleen J. Roth, Robert Hollon, and Theron Blakeslee

Published By

The Institute for Research on Teaching
College of Education
Michigan State University
East Lansing, Michigan 48824-1034

November 1987

This work is sponsored in part by the Institute for Research on Teaching, College of Education, Michigan State University. The Institute for Research on Teaching is funded from a variety of federal, state, and private sources, including the United States Department of Education and Michigan State University. The opinions expressed in this publication do not necessarily reflect the position, policy, or endorsement of the funding agencies.

Institute for Research on Teaching

The Institute for Research on Teaching was founded at Michigan State University (MSU) in 1976 by the National Institute of Education. Following a nationwide competition in 1981, the NIE awarded a second five-year contract to MSU. Funding is also received from other agencies and foundations for individual research projects.

The IRT conducts major research projects aimed at improving classroom teaching, including studies of classroom management strategies, student socialization, the diagnosis and remediation of reading difficulties, and teacher education. IRT researchers are also examining the teaching of specific school subjects such as reading, writing, general mathematics, and science and are seeking to understand how factors outside the classroom affect teacher decision making.

Researchers from such diverse disciplines as educational psychology, anthropology, sociology, and philosophy cooperate in conducting IRT research. They join forces with public school teachers who work at the IRT as half-time collaborators in research, helping to design and plan studies, collect data, analyze and interpret results, and disseminate findings.

The IRT publishes research reports, occasional papers, conference proceedings, a newsletter for practitioners, and lists and catalogs of IRT publications. For more information, to receive a list or catalog, and/or to be placed on the IRT mailing list to receive the newsletter, please write to the IRT Editor, Institute for Research on Teaching, 252 Erickson Hall, Michigan State University, East Lansing, Michigan 48824-1034.

Co-Directors: Jere E. Brophy and Andrew C. Porter

Associate Directors: Judith E. Lanier and Richard S. Prawat

Editorial Staff
Editor: Sandra Gross
Assistant Editor: Sally B. Pratt

Abstract

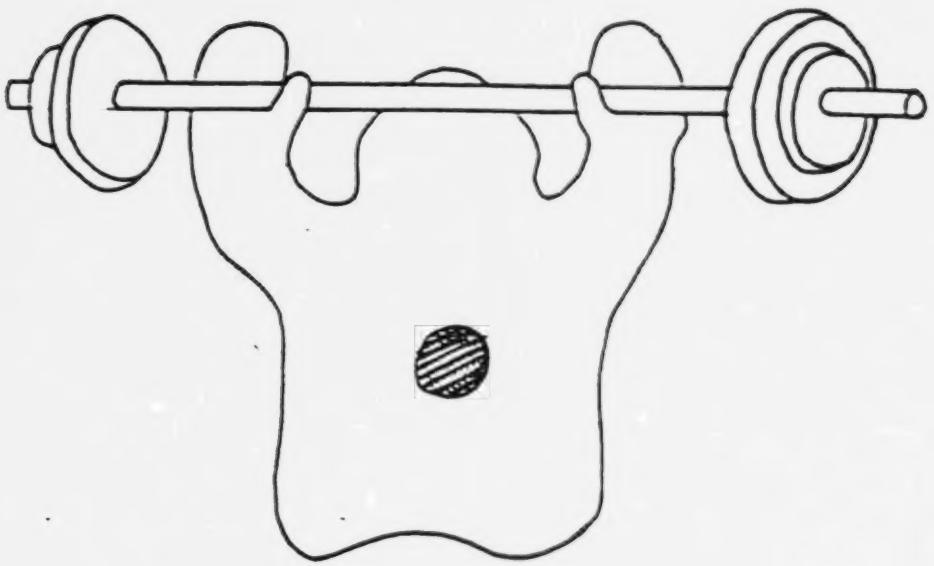
The Power Cell is a set of instructional materials about cellular respiration that were used in a research study of middle school science teaching during 1985-86. The Middle School Science Project investigated ways to help middle school science teachers use teaching strategies that have been identified in earlier studies as particularly effective in promoting meaningful conceptual-change learning. Such learning requires students to go beyond memorization of facts and terminology and to really make sense of scientific explanations of phenomena. For students, such learning in science often requires them to go through a difficult process of conceptual change, reshaping and abandoning ideas or misconceptions that they have developed from experience and have believed for a long time.

One group of teachers in the study received The Power Cell Teacher's Guide as a major source of support in implementing conceptual-change teaching strategies. They used these materials as they taught a unit about photosynthesis in their classrooms. Researchers observed and interviewed the teachers and gave pretests and posttests to assess student learning. The Power Cell materials were found to be helpful to teachers, and students using these materials were more successful in undergoing conceptual change than students who did not use the materials.

The materials include an introductory description of students' difficulties learning about cellular respiration, a student text with accompanying comments and suggestions to teachers, a set of overhead transparencies, and suggested laboratory activities.

THE POWER CELL

Teacher's Guide to Respiration



Written by

Charles W. Anderson, Kathleen J. Roth,

Robert Hollon, and Theron Blakeslee

Illustrated by

Saundra L. Dunn

About the Authors

Charles Anderson, coordinator of the Science Teaching Project, is a senior researcher with the Institute for Research on Teaching and associate professor of teacher education at Michigan State University. Kathleen Roth, a member of the project, is also an IRT senior researcher and assistant professor of teacher education at MSU. Robert Hollon, former research assistant on the project, is assistant professor of teacher education at the State University of New York--Albany. Theron Blakeslee is a research assistant with the project. The illustrator Saundra Dunn is a research assistant with the Institute for Research on Teaching.

Table of Contents

Page

I. Introduction. Please read this first. It contains essential information to help you understand and use the materials..... 1

A. Learning About Respiration: Memorizing or Making Sense?..... 1

B. Critical Barriers to Understanding Respiration..... 3

C. Chart of Respiration Issues..... 6

D. Teaching Strategies for Overcoming Critical Barriers..... 7

E. Suggested Timeline..... 8

II. Student Text and Accompanying Comments to the Teacher..... 9

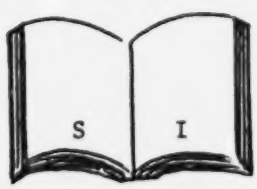
III. Overhead Transparency Set and Accompanying Comments to the Teacher.....37

IV. Demonstration and Laboratory Activities.....40

A. Demonstration: Does Exhaled Air Contain More Carbon Dioxide Than Inhaled Air?.....41

B. Laboratory Activity: Exercise, Energy Needs, and Cellular Respiration.....43

ORGANIZATION OF PAGES IN THIS MODULE



Student Pages	Instructor Pages
Pages with instructional materials to be used by students are on the left.	Pages with information for instructors are on the right side.

I. INTRODUCTION

A. Learning About Respiration: Memorizing or Making Sense?

What is respiration?

How do we use the food that we eat?

Where do our bodies get the energy that we need?

If these questions were posed to your middle school students after they had studied respiration, how do you hope they would respond? What are the most basic, critical concepts you would want them to remember? How could you tell the difference between students who understood respiration and those who memorized correct answers?

This unit is based on a research project in which we have tried to develop answers to the questions above and to develop methods of teaching that lead to real understanding. We have found that students often learn to memorize (then quickly forget) acceptable answers to test questions. All the while, though, they retain other ideas that are in conflict with what they hear in class. Within a few months, only their original incorrect ideas remain.

For instance, compare definitions of respiration given in middle school life science textbooks with definitions given by middle school students who have studied respiration.

Definitions of respiration

From middle school life science texts	From middle school students who have studied respiration
The releasing of energy from food in which the energy is made available for use by an organism's cells	Breathing
Process in which organisms break food down into carbon dioxide, water and energy	The intake of oxygen and the removal of carbon dioxide
The changing of food materials to get energy	Getting rid of excess water
Oxidation (burning) of food	The raising and lowering of the diaphragm to inhale oxygen and exhale oxygen
	The taking in of oxygen to help feed cells and the giving off of carbon dioxide as waste

The textbook definitions refer to cellular respiration, the process by which organisms obtain energy from food. The students, on the other hand, give definitions that don't mention food or energy at all!

It might be that the confusion shown by students in their definitions of respiration simply reflects ambiguity in the meaning of the word. After all, the definitions given by students are correct in some contexts. Unfortunately, the problem goes deeper than ambiguity in definition. The students' incorrect definitions are part of a larger pattern in which students do not understand how organisms use food and obtain energy. Compare students' explanations of how an animal uses food with what is written in life science textbooks:

Question: How does an animal use the food that it eats?

From middle school life science tests	From middle school students who have studied respiration
Animals obtain energy from their foods. Some foods supply energy for motion and muscular activity, while others are used for growing and other functions.	They store the food for when they can't get food
All organisms get the energy they use from food. Food contains energy. Food is the "fuel" for all living things.	It digests the food and lives with food
Living things use the chemical energy, stored in food, to carry on life processes, such as growth and reproduction.	In the cells for them to live
	An animal uses the food it eats for building and repairing and to fight disease
	It might store it for the upcoming winter, and to repair body parts

---

What is wrong here? Why do students sometimes have so much trouble remembering relatively simple ideas? The teaching materials in this unit are based on one answer to this question. The answer arises from extensive research comparing students' ways of thinking about natural phenomena with scientific experts' ways of thinking about the same phenomena. In general, this research shows that the students think and act in ways that are perfectly sensible to them, but that are incompatible with scientific thought.

Thus, most of the incorrect answers quoted above are not just guesses by students who don't know. They had beliefs about respiration, food, and energy before they began to study. Sometimes those beliefs ("Respiration is another word for breathing," for example) are more powerful than what they read in their science texts.

The presence of students' alternate ways of thinking makes the learning of science a far more complicated process than scientists normally imagine. For these students learning about respiration is not simply a matter of absorbing or memorizing scientific content. Instead, they must reassess and change their commonsense, everyday understandings of the world. Furthermore, they must abandon misconceptions or habits of thought that have served them well all their lives in favor of new and unfamiliar ideas.

This is not an easy task! These old habits of thought often persist even after students have apparently learned the scientific alternatives. Many students become quite good at learning what is expected of them to pass science tests while continuing to use their old ideas in "real world" situations. The students quoted below show another common pattern of incomplete learning.

Question: Where do we get the energy we need to grow and live?

Sandy: Food and sun

Laura: From food and exercise

Terry: Food, water, exercise, sleep to be strong

Jamie: From food, water

Susan: From the sun, from food and water

All of these students correctly identified food as a source of energy, but they had lots of other incorrect ideas, too! Students often incorporate new ideas into their belief systems without giving up their old, incorrect beliefs. For students with such mixtures of ideas, science doesn't seem particularly clear or logical. No wonder they rely on memorization rather than trying to make sense of the science they study!

We have adopted a phrase from David Hawkins and describe students' naive ways of thinking that interfere with their understanding of scientific thinking as "critical barriers" to the learning of science. In our research we have tried to understand the critical barriers to student learning about central topics in the science curriculum and to use those understandings to define teaching strategies that will help students overcome those barriers.

B. Critical Barriers to Understanding Respiration

Our discussion of critical barriers is organized around four questions. We have found that these questions make sense to most students, but that they answer them in ways quite different from scientists. Scientific answers and student answers to these important questions are contrasted below.

1. How do our bodies get energy? Biologists recognize only a single source of energy for the life processes in most organisms: the vast array of organic compounds known collectively as food.

Food that is manufactured (by plants) or consumed (by animals) contains chemical potential energy. That energy is released for use by organisms when that food is combined with oxygen in the process of cellular respiration. Since cellular respiration takes place in each individual cell, all aerobic organisms must have a mechanism for delivering food and oxygen to every cell.

Adults who are not gaining weight have almost no use for food except cellular respiration; only a small amount of food is used for repair and maintenance functions. Children incorporate some of the food they eat into their bodies as they grow, but they also use most of their food as a source of energy: an input to cellular respiration.

Many middle school students say that we get energy from food, but that statement means something quite different to them from what it means to scientists. This is partly because they often define food differently from scientists. Many students, for example, consider water or minerals, which are not organic compounds and do not supply energy, to be forms of food.

Students' naive definitions of energy are even more difficult. They commonly associate energy with "feeling good," so it seems reasonable to them to say that we get energy from water, or exercise, or sleep, as well as food.

Thus students can gain a meaningful understanding of how our bodies get energy only by learning new, and more restricted, definitions of food and energy, and by understanding how they can be applied to living systems.

2. Why do we eat? Biologists recognize that the ultimate fate of most of the food that we eat is to be used in cellular respiration. In order for this to happen, the complex molecules of food must be broken into simpler molecules that are soluable in blood; this is the process of digestion. Food leaves the digestive tract and enters the blood in the small intestine, along with water, vitamins, and minerals. It then goes to the cells, where it is combined with oxygen in the process of respiration.

Most students can successfully follow food only as far as the stomach or the small intestine, where they know that it is "digested." They are generally aware that feces are one product of the digestive process. Students are much less commonly aware, however, that food enters the bloodstream or of how it is used by the cells. Thus they lack explanations of why we eat that focus on body functions and processes.

3. Why do we breathe? Biologists recognize that we need oxygen for only one purpose: to combine with food in cellular respiration. Oxygen that we breathe enters the blood, which carries it to the cells, where it is combined with food to supply the cells with energy. One of the waste products of cellular respiration is carbon dioxide, which the blood carries from the cells back to the lungs, where it reenters the air and is breathed out.

In contrast, some student explanations of why we breathe are presented in the table below.

These students are typical of many middle school students. They associate breathing with the nose and lungs, rather than the whole body, and they have little idea of how it is used beyond knowing it is necessary to keep us alive. Students hardly ever associate breathing with eating or our use of food.

Humans get oxygen from the air they breathe.

	Questions: a. Where does the oxygen get used by the body?	b. How does the oxygen get used?
Jenny:	Lungs	It lets us breathe.
Aaron:	Lungs	We breathe it.
James:	The nose and the mouth.	It keeps you alive.
Sheila:	The oxygen is used in your blood and cells.	The oxygen is used to keep the blood healthy and produce more blood, keep cells healthy, and produce more cells.

Thus, students come to understand the process of respiration only when they give up simplified, unconnected, and nonfunctional explanations of breathing and eating. They must see how the breathing and eating are united by the fact that both food and oxygen are needed for cellular respiration and that our body systems function together to deliver those substances to our cells.

4. What is a good explanation? Consider the explanations of how we use oxygen offered by students in the chart above. It is notable that the students' explanations don't really explain anything. None of the answers offers an explanation of how oxygen is used in terms of body functions and processes. Instead, the students find new ways of saying that we need to breathe.

Scientists on the other hand, expect functional explanations (for example, "Animals need food because their cells use food as a source of energy.") Biologists think about the function that each substance plays in the internal workings of an organism. They seek to understand not just whether or not an organism needs a particular substance to stay alive; they want to know what happens to that substance inside an organism. How does the animal use it? Thus, an essential part of learning about respiration is learning to develop appropriate functional explanations and definitions.

We have chosen to emphasize these four issues because the concepts they involve are absolutely essential for students to make sense of respiration. Unfortunately, most textbooks and courses fail to treat these concepts adequately, forcing students to grapple with more advanced and difficult concepts before they have mastered these fundamental ideas. In an attempt to make sure that students come to understand the central ideas, we have carefully limited the amount of scientific terminology introduced, and we have not discussed respiration at a molecular level.

C. Chart of Respiration Issues

The following chart is our way of stating the objectives for these materials. Our research indicates that most middle school students begin instruction with beliefs like those in the column labeled "Naive Conceptions." These materials are designed to help them change to the scientific thinking in the column labeled "Goal Conceptions."

Respiration Issues and Conceptions

Issue	Goal Conceptions	Naive Conceptions
Implicit definition of respiration	Respiration is the process by which all cells obtain energy from food.	Respiration is breathing which occurs only in animals.
Nature of food	Food is matter that organisms can use as a source of energy.	Food is the stuff that organisms eat.
Function of food	Food supplies the energy that cells need for life processes.	Food keeps organisms alive.
Source of energy	The only source of energy for any organism is the energy stored in food.	Organisms get energy from many different sources.
Energy transformation	Energy stored in food is released in a form that can be used by cells.	Food energy is used directly (no notion of energy transformation).
Matter transformation	Food is chemically combined with oxygen to create carbon dioxide and water, accompanied by the release of energy.	Food is digested and excreted. Oxygen is changed into carbon dioxide. These two processes are not related to one another.
Movements of reactants and products	Food and oxygen are supplied to all cells via the respiratory and circulatory systems. Carbon dioxide and water are removed from cells by these same systems.	Food goes to the stomach, gets digested and is excreted. Oxygen goes into the lungs and carbon dioxide comes out. (No notion of distribution to cells.
Nature of energy	Energy changes from one form to another: light-->stored energy in food-->energy for life processes-->heat.	Energy is confused with matter, which contains energy, and gets used up (like fuel).

D. Teaching Strategies for Overcoming Critical Barriers

What kinds of teaching strategies can help students give up or modify their commonsense ways of thinking about eating and breathing in favor of the concept of cellular respiration? What can teachers do to encourage students to make sense of scientists' ways of thinking and to discourage students from memorizing their way through another science unit?

For many students, the naive ways of thinking described above are deeply ingrained. We have found that for such students even the best explanations are not enough. Replacing easy and familiar ideas with more abstract biological conceptions is a difficult process. It requires that students become actively involved in thinking about the subject, that they receive corrective feedback from teachers about their thinking, and that they have many opportunities for practice and application.

For these reasons, the materials are designed to help teachers use the following general teaching strategies:

1. Getting students involved in thinking about the subject. The materials include questions that will encourage students to think about what they know about their bodies, as well as other plants and animals, and to make links between their knowledge and the concept of respiration. The student text, for example, begins with questions asking students for their ideas about what happens to the food we eat and the oxygen we breathe. We have found that students are more interested in reading the text once they realize that it is going to discuss something they know about from their personal, everyday experiences. This approach also communicates to students that teaching and learning involve their own ideas and their thinking.

2. Diagnosing student difficulties and providing corrective feedback. An important part of teaching is understanding how students are thinking about respiration. The commentary for teachers describes what each question is designed to reveal, the appropriate scientific responses for each question, and the range of answers students are likely to give. Suggestions for appropriate feedback to common student answers are given.

3. Creating dissatisfaction with naive ways of thinking. Many students enter science classes expecting to memorize facts and definitions, but not to really change how they think about the world. The activities in these materials provide students with a variety of opportunities to see that their present ways of explaining and predicting scientific phenomena do not work as well as scientific explanations. For example, students are asked to make predictions and to later use new concepts to explain why their predictions were wrong. Making explicit to students such contrasts between their ways of thinking and scientists' ways of thinking is a powerful teaching strategy. By posing an intriguing dilemma in which students' own ideas are challenged, such contrasts capture students' attention and make students more willing to puzzle through problems.

4. Providing opportunities for practice and application. To come to understand the importance of respiration, students need to see how the concept can be used to explain many different phenomena in satisfying ways. In addition, students who are used to memorizing their way through science classes need much practice and support as they are learning how to think at a

conceptual level. For these two reasons, the materials include many questions and activities that allow students to practice and apply new concepts. These activities help students see the power of the concept of respiration in explaining a variety of phenomena. Since the basic purposes of scientific theories are to explain and predict, we feel that the questions asking students for explanations and predictions are especially important.

E. Suggested Timeline

These materials are designed to support you in helping students make the transition from commonsense thinking to more accurate scientific ways of thinking. We hope that you will select those activities that would be appropriate for your students. We recognize that you will probably not want to or be able to use all of the materials. In addition, you may have other materials that you believe could effectively complement these materials.

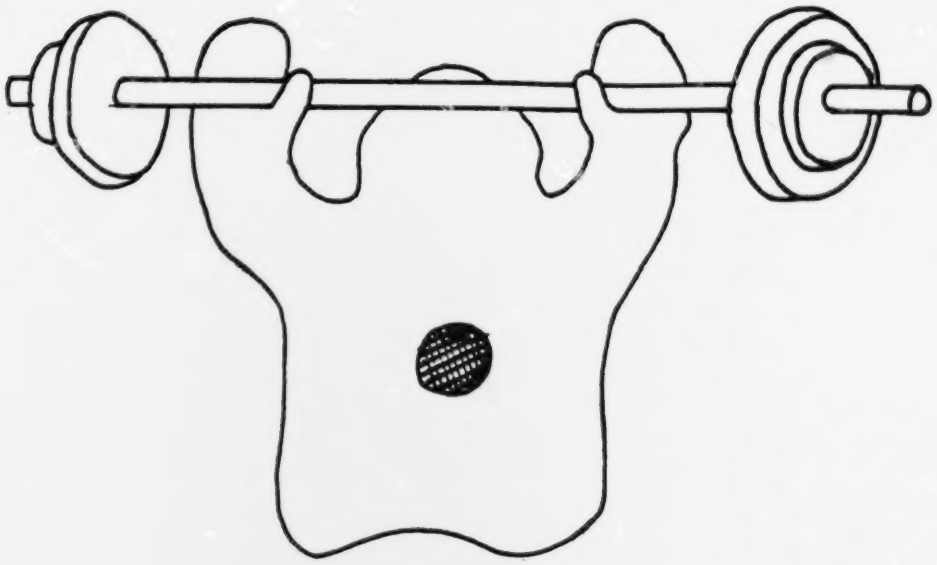
The materials we are providing are of three types. Part II of this guide contains student text materials. This is in a workbook format so that students can answer questions directly on text pages. In Part III, a copy of a transparency set and notes for the teacher about their use are provided. Part IV includes one laboratory activity and one demonstration. In each part, copy-ready student materials are contained on the left-hand pages and information for teachers on the right-hand pages.

The timeline below suggests one way of using these materials. The actual time taken for various activities, of course, depends on many different factors.

The order of activities is flexible, but the demonstration laboratory activities (Part IV) are designed to be done after the process of respiration has been explained to the students (pages 16-21 of the student text).

Number of Lessons	Suggested Activities	Pages in the Guide
1	Chapters I and II in student text	9 - 15
1	Chapter III in student text Transparency 2	16 - 20 41
1	Chapter IV in student text Transparency 1	21 - 24 39
1	Chapter V in student text Transparencies 1-6, 8-9	25 - 30 after page
2	Demonstration and laboratory activity	40 - 45
1	Chapter VI in student text Transparencies 7, 10-12	31 - 36 after page 39

THE POWER CELL



Written by

Charles W. Anderson, Kathleen J. Roth,

Robert Hollon, and Theron Blakeslee

Illustrated by

Saundra L. Dunn

II. STUDENT TEXT

Contents of the Student Text

I. Introduction. S-10

II. Where Do Our Bodies Get the Energy We Need. S-12

III. What Happens to the Food We Eat S-16

IV. What Happens to the Air We Breathe. S-21

V. What Is Respiration S-25

VI. Respiration and Other Living Things S-31

CHAPTER I

INTRODUCTION

Every day you breathe in and out about 20,000 times. In your lifetime so far, you've breathed in and out about 9,000,000 times! You've also eaten food three to four times a day each day that you've been alive. That's about 15,000 meals in your lifetime so far! Eating and breathing are obviously very important to you--you do them both all the time. You have to eat and breathe to stay alive.

But have you ever wondered why your body needs so much oxygen and food? What happens to all that air and food you take into your body? Do you know why breathing and eating are necessary for life? Most of us eat and breathe every day and have no idea why! In this unit, you will learn why you eat and breathe all the time. You will get to know something about things going on inside your own body right this very minute. Then you will understand why it is necessary for you to breathe and eat.

In this unit we will discuss four questions. You might have some ideas about those questions now, so take a minute to think about them and write down your ideas.

1. Where do our bodies get the energy we need? _____

_____

_____

2. What happens to the food we eat? _____

_____

_____

_____

The unit is structured around these four questions. Students will probably answer them incorrectly at this point. Important patterns to look for are described below.

1. Many students will probably mention food in response to this question, but only a few will be aware that food is our only source of energy. The word "*energy*" will not have the same meaning for most students as it does for scientifically trained adults.

2. Students will give a variety of answers to this question, but few will successfully trace food through the digestive system to the bloodstream and the cells.

3. What happens to the air we breathe in? _____

_____

_____

_____

4. What is respiration? _____

_____

_____

In the next four chapters you will learn how biologists answer each of these four questions. Read on, and see if your answers compare with the biologists' answers.

3. Students will probably give a variety of answers, but few will be able to trace oxygen from the lungs, through the bloodstream, to the cells.

4. Some students will have no idea what respiration is; others will identify respiration with breathing. Probably no students in your class will be able to identify the word with the process of cellular respiration.

CHAPTER II

WHERE DO OUR BODIES GET THE ENERGY WE NEED?

We all need energy all the time.

We need energy to grow.

We need energy to move.

We need energy to eat.

We need energy to think.

We even need energy to dream!

Your body is made up of trillions of cells, more cells than there are people in the world. Every one of those cells needs a constant supply of energy to survive. If our cells ever run out of energy for even a few minutes, then we will die.

Other living things are like us. Animals, plants, and even bacteria all need energy to live and grow. All living things are made of cells (though some, like bacteria, contain only a single cell!). Every cell in every living thing must have a constant supply of energy.

Where does that energy come from? Where do you think our bodies get energy?

Can we get energy from water? _____

Can we get energy from vitamins and minerals? _____

Can we get energy from exercise? _____

Can we get energy from sunlight? _____

Can we get energy from food? _____

Much of the material in this chapter will be a review for students who have previously studied the photosynthesis unit from this project (The Power Plant). We recommend that you monitor students' responses to the questions in this chapter, reteaching these concepts as necessary.

This series of questions focuses on common student misconceptions about how we get our energy. Hardly any students will say that we get energy only from food. The students' difficulties are due in part to misunderstandings about the nature of energy and its sources.

Can we get energy from water?

No, we can't. We must have water to survive, but water is not a source of energy. Even all the water in the world could not keep us alive if our cells ran out of energy.

It might help you understand that water is not a source of energy for living things to think about the following situation: Could you live by drinking water and not eating any food?

No, you would soon get very weak and sick. Some people go on "fasts" for religious reasons or to lose weight. They eat no food, but they do drink water. Even if they drink lots of water, they become weaker. People who drink water but do not eat will eventually die, because their bodies have no source of energy to keep their cells alive.

Can we get energy from vitamins and minerals?

No, we can't. You might have heard people say that vitamins and minerals will "give you energy," but that is not really true in a scientific sense. Vitamins and minerals help our bodies in a number of ways, but they do not provide us with energy.

Can we get energy from exercise?

No, we can't. We need energy in order to exercise. Running, dancing, lifting weights, riding bicycles--we need energy to do all of these exercises. So exercise is a way that we use energy; it is not a source of energy. The more we exercise, the more energy we need!

This section explains to students what is wrong with the other ideas about sources of energy. You may want to discuss with them how the scientific term "energy" is different from common uses of the word.

Water is essential for life because all life processes take place in a water solution. Water also plays a role in a vast number of biochemical reactions, including respiration. However, it does not supply chemical potential energy.

Minerals help maintain solvent balances and play a role in many biochemical processes. Vitamins are catalysts in various reactions. However, neither is used by the body as a source of energy.

Can we get energy from sunlight?

No, we can't. Sunlight is a form of energy, but unfortunately we can't use it. We could stand out in the sun all day and still die from lack of energy! Neither humans nor any other animals can get energy directly from sunlight.

Plants are different from animals in this respect. Special leaf cells in green plants can use the energy of sunlight to make food. This is the process of photosynthesis. Just like cells in our bodies, cells inside a plant need energy to survive. Even plant cells, though, cannot use the energy in sunlight directly. They use sunlight to make food: kind of sugar called glucose. They change the energy from the sun into energy stored in food. Plant cells get their energy from this food, not directly from sunlight.

Can we get energy from food?

Yes, we can! In fact we must get energy from food. All of the trillions of cells in our bodies need food because food is their only source of energy. Every cell in every living thing needs food for the same reason. Food is their only source of energy.

Energy is so important to living cells that it is a part of biologists' definition of food:

FOOD refers only to materials that contain energy for living things. All living things must have food, and the energy it provides, to live and grow.

This passage reviews important similarities and differences among plants and animals. In this unit, which focuses on the use of food rather than its production, the similarities are more important than the differences.

This definition of food will be used throughout the unit.

Is water a kind of food? _____ Why or why not? _____

_____

Are vitamins and minerals food by the definition given above? _____ Why or why not? _____

_____

Look back at your answers to the questions on p. 12. How would you change your answers now?

Can we get energy from water? _____

Can we get energy from vitamins and minerals? _____

Can we get energy from exercise? _____

Can we get energy from sunlight? _____

Can we get energy from food? _____

Why do we need do eat? _____

_____

_____

Students should answer the questions about water and vitamins by applying the definition of food. Other answers are unsatisfactory at this point.

Students should now be able to answer all of these questions correctly.

The final question in this chapter leads into the next chapter. Check your students' answers to see how many focused on the function of food in our bodies: to supply us with energy. Many students will probably give other, less satisfactory explanations at this point.

CHAPTER III

WHAT HAPPENS TO THE FOOD WE EAT?

What was your answer to the last question on page S-15? Here are three possible answers; which one do you think is best?

We need to eat because we would die without food.

We need to eat because food helps us live and grow.

We need to eat because food is our cells' only source of energy.

All three statements are correct, but they are not all good explanations of why we need to eat. Scientists would say that the third answer is the best one because it explains something about how our bodies use the food that we eat: Food is our cells' only source of energy. A good scientific explanation always tells why or how something happens.

All cells need food as a source of energy. They also need food to grow. That answer, though, leads to another question. How does food get to all of your cells? When you swallow food it goes to your stomach, but your body has trillions of cells and they're not all in your stomach! How does that food reach the cells in your brain? In your toes? In your knee cap? In your thumb? Do you know?

How does food get to all of your cells?

Let's try to answer our question by following a piece of food that you eat. A bite of apple, for instance. That bite of apple is really a mixture of many different things. It contains many things that your body can use: water, vitamins, and minerals. Since it is food, we know it also contains _____ that your body can use (look back at the definition of food, if you can't fill in the blank.) It also contains some things that are useless to you: bits of dirt, and bacteria, and tough fibers that your body cannot use.

The opening passage in this chapter emphasizes the importance of functional explanations in science, contrasting them with explanations that merely restate our need for food.

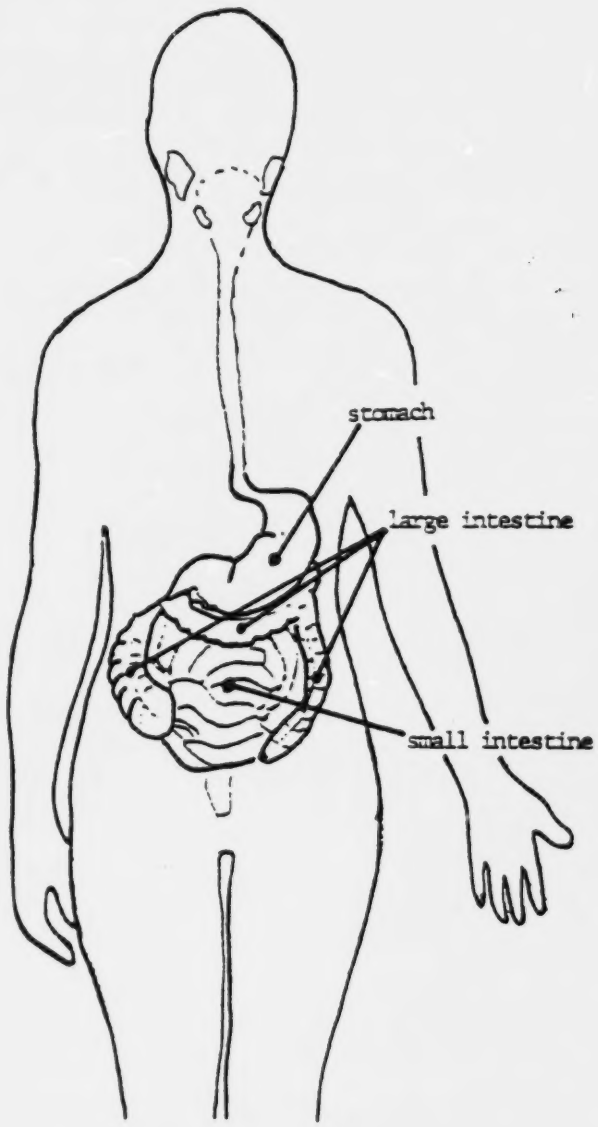
To understand cellular respiration students must focus on the functioning of individual cells. This passage asks students to start thinking about how our bodies are designed to meet the needs of each individual cell.

Suppose you take a bite of apple that has all these things in it. You chew them up and mash them up and mix them with saliva in your mouth. Then you swallow. Let's follow the piece of apple from there. You can use the picture on this page to help you.

To your stomach and small intestine? The apple's first stop is your stomach. It is mixed with digestive juices and sent on to your small intestine. There, different parts of your bite of apple go different ways.

The useless parts of the apple--the fibers, bacteria, and dirt--keep right on going. They go from the small intestine to the large intestine and then right out of your body: feces!

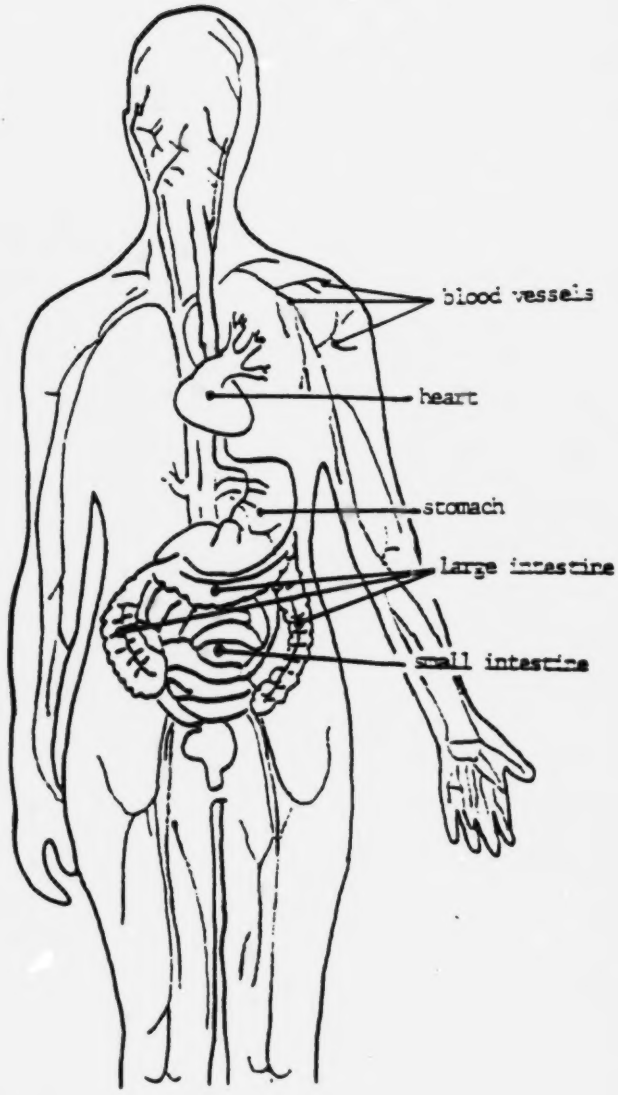
What about the useful parts of the apple, though, the water and vitamins and minerals and the energy-containing food that your cells need? Instead of going on to the large intestine, they are carried to all the cells of your body. Do you know what takes them there?



This section is not intended as a complete presentation of the operation of the digestive system. The key point that students must understand is that food goes from the digestive system into the blood, which carries it into the cells.

To your blood? Food and other useful substances go through the walls of your small intestine and into tiny blood vessels. Then the blood carries those useful substances all over your body. A blood vessel passes near every living cell in your body! The cells take the food they need from your blood.

Most people don't realize how many tiny blood vessels they have in their bodies. We tend to think about the big vessels that we can see by looking carefully at our skin. But there are millions of tiny blood vessels in our body. If we lined them up end-to-end, they would go twice around the earth !



Why do we need so many tiny blood vessels? _____

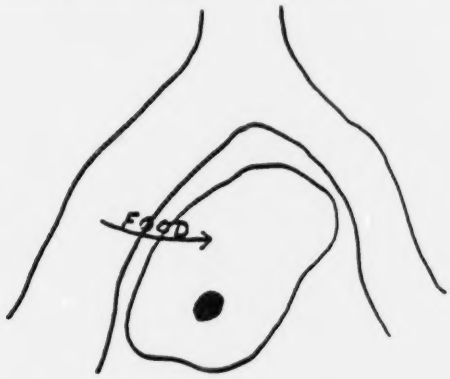
_____

_____

Transparency 2 is useful for discussing this section of the text.

The best answers to this question should emphasize the function of the blood just discussed. Blood vessels do not need just to reach every cell; they need to carry food to every cell.

To your cells? Your cells take the food they need out of your blood. Then they do one of several different things with it:



--Some of the food is used by cells to divide and make new cells. That's how you grow.

--If you eat more food than you need, some of the food is stored for future use. Fat is your body's way of storing extra food!

--Most of the food that reaches your cells is broken down to supply energy.

Explain how a muscle cell in your finger gets the food it needs to give it the energy needed to write this answer. _____

_____

_____

Even if you don't eat for several days, you won't die right away. Your blood can keep carrying food to all your cells. Where does that food come from? _____

_____

_____

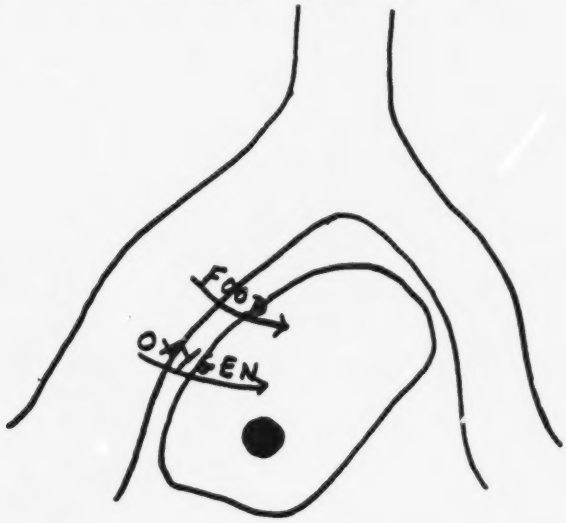
Using food in your cells

Blood carries food to the cells. But the cells cannot use the energy in the food until another substance arrives in the cell. That substance is oxygen. Our cells cannot use the energy stored in food until oxygen combines with the food. Then the energy is released.

Students should now be able to give correct functional explanations in response to this question, tracing the food from the digestive system into the blood, and then to the cell in the finger.

The statement about food being stored (above) provides students with a clue about the correct answer to this question. Note that individual cells have a very limited capacity for food storage and cannot survive without food.

Pumping food into a cell is a little bit like pumping gasoline into a car. The car cannot use the energy in the gasoline tank to move until the gasoline is burned. Similarly, the cell cannot use its food energy until oxygen arrives and combines with the food. Oxygen reacts with food to release energy that the cell needs in order to live and do its work.



Using the idea in this paragraph, explain why we need to breathe.

This question looks forward to the next chapter, which discusses how cells' oxygen needs are met. Note that oxygen is introduced as a substance that is needed for a single specific purpose: to get energy from food.

CHAPTER IV

WHAT HAPPENS TO THE AIR THAT WE BREATHE?

How did you answer the last question on page 20?

Many people think that we breathe because we need oxygen to live. They are only partly right. They have left out an important part of the explanation of why we breathe. They have not explained <u>why</u> we need oxygen or <u>how</u> the body uses that oxygen. If you understood Chapter III, you probably included a <u>reason</u> why our bodies need oxygen in your answer to the question on page 20. Compare your answer to this one:

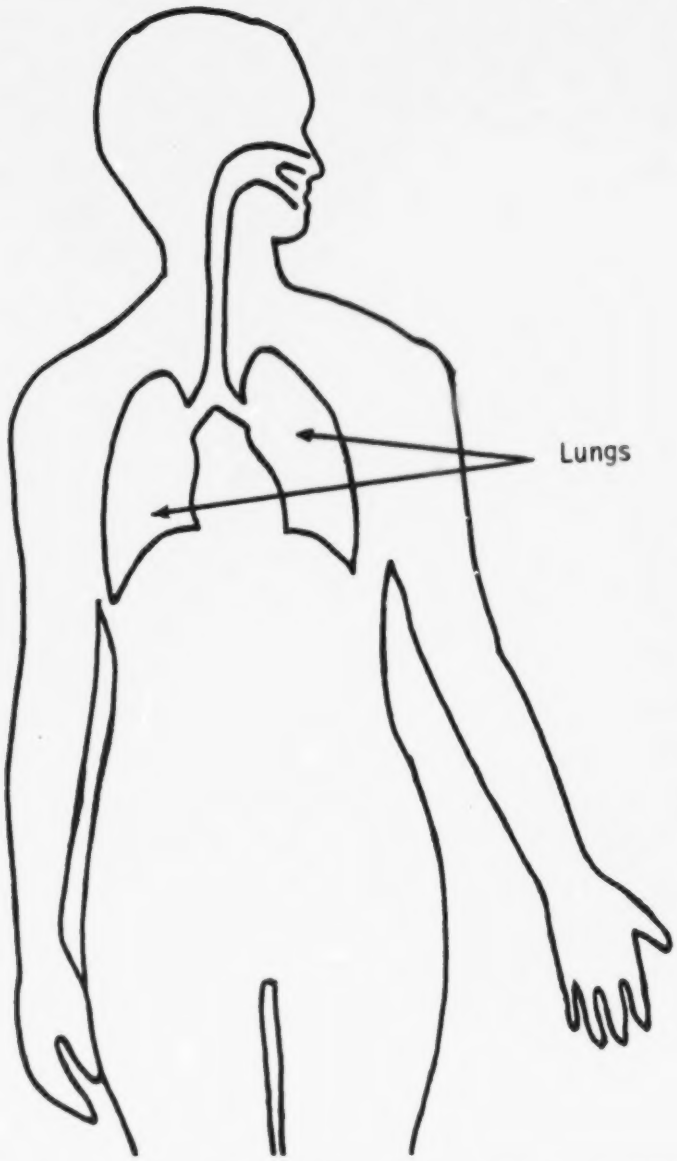
<u>We breathe so that our cells can get oxygen to combine with food. That is how our cells get the energy that is stored in food</u>.

That is a good answer to the question. The cells of all plants and animals get their energy by combining food with oxygen. You have learned how food reaches your cells, but what about oxygen? Do you know how it reaches your cells? Let's answer that question by following one breath of the air that you breathe.

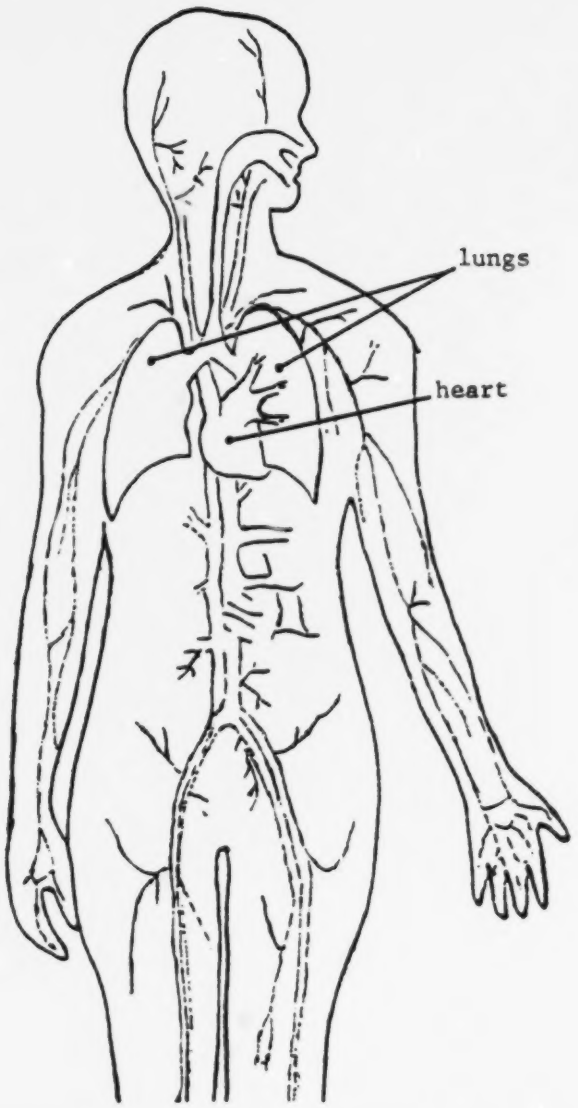
<u>How does oxygen get to all of your cells</u>?

Air contains oxygen, which your cells need, as well as many other substances that your cells do not need. Some of those other substances are gases such as nitrogen, carbon dioxide, and water vapor. Air also has bits of dust and smoke and pollen in it. You can use the picture on the next page to follow what happens to the air that you breathe.

This chapter, like Chapter III, opens with a discussion of the importance of functional explanations in biology.



To your lungs? With every breath, your lungs fill up with air. Most of that air, including all of the substances that your body doesn't need, you breathe right back out again. But you don't breathe out all of the oxygen that you breathe in. Some oxygen stays in your body and goes to all your cells. Do you have an idea how it gets to your cells? (Think about how food gets to your cells.)



To your blood? That's right, your blood carries both food and oxygen to your cells! The inside of your lungs is sort of like a sponge. Lungs have lots of tiny spaces for the air to go into, and each one of these spaces is surrounded by tiny blood vessels. Some of the oxygen in the air goes into the blood.

To your cells? From your lungs the blood takes oxygen to the cells in all parts of your body. Your cells get the energy they need by taking both food and oxygen out of your blood.

Transparency 1 is useful for discussing this section of the text.

Using what you know

You now know that:

1. All of your cells get their energy by combining food with oxygen.

2. Food reaches your cells because your blood carries it there from your small intestine.

3. Oxygen reaches your cells because your blood carries it there from your lungs.

Try using these ideas to answer the questions below.

1. Suppose all the parts of a person's body continued to work perfectly except for one thing: Blood stopped circulating to the lungs. What would happen to that person? Why? _____

_____

_____

_____

2. Suppose all the parts of a person's body continued to work perfectly except for one thing: Blood stopped circulating to the small intestine. What would happen to that person? Why? _____

_____

_____

_____

3. How is breathing connected with eating? _____

_____

_____

_____

Students' answers to the questions should be evaluated on the basis of how well they used the three ideas listed here.

1. Answers to this question should use the first and third ideas. Oxygen is essential if our cells are to have energy, and it can reach our cells only if blood carries it there from the lungs.

2. Answers to this question should use the first and second ideas. Food is our cells' source of energy, and it can reach our cells only if blood carries it there from the small intestine.

3. Answers to this question should focus on the first idea. We get energy by combining food from eating with oxygen from breathing. This question also looks forward to the next chapter, in which the process of respiration is introduced.

CHAPTER V

WHAT IS RESPIRATION?

How did you answer the last question on page 24? Many people think that breathing and eating are two completely different things. They think breathing and eating are connected only in that we need to do both of them to stay alive. Now, though, you should know better. Breathing and eating are involved in the **same** process, or job, in the body. A good answer to the question would be something like this:

> Breathing is connected with eating because our cells combine food and oxygen to get energy.

Biologists have a name for this process that involves combining food and oxygen: That name is **respiration**. Biologists define respiration like this:

> Respiration is the process by which cells get energy by combining food and oxygen.

How did you define respiration on page 11? Look back and see. If you knew the word, you probably defined respiration as another word for "breathing." This is a correct definition; you can find it in the dictionary. However, that is not how biologists define respiration.

Notice that the biologists' definition includes both food and oxygen in the same process. We eat **and** breathe for the same reason--to release energy from food to our cells to use.

Biologists sometimes call this process **cellular** respiration to emphasize that it takes place in every single cell, not just in your lungs. Right this very second, every one of your trillions of living cells is getting its energy from cellular respiration!

The first paragraph on this page contrasts the biological view of breathing and eating with the view commonly held by students: that the processes are separate.

This paragraph contrasts the biological definition of respiration with the most common student misunderstanding about the meaning of the word.

How does cellular respiration work?

You eat many different kinds of food, but your body changes all of them to the sugar glucose or a similar substance. Glucose is the kind of energy-containing food that cells use for respiration. When cells combine glucose (food) and oxygen, they release the energy stored in the glucose. The cells use that energy to live and grow.

Energy is not the only product of cellular respiration. There are also two waste products that the cell doesn't use. These waste products are carbon dioxide and water. An equation is one way to describe the process of respiration:

glucose + oxygen ----------> carbon dioxide + water + ENERGY

This equation means that glucose (food) and oxygen react and combine together to change into carbon dioxide and water. Energy is released as part of this reaction occuring in every cell of your body.

Right now, every one of your cells is converting glucose and oxygen to carbon dioxide, water, and energy. Every living plant and animal cell gets energy from food in this way, using glucose and oxygen and converting them into carbon dioxide and water.

The air that you breathe out has less oxygen and more carbon dioxide than the air you breathe in. What happened to the oxygen that you breathed in? ____

This passage actually oversimplifies the process of respiration. The oxidation of glucose is actually a two-step process. In the first step, glycolysis, the six-carbon glucose molecule is broken into two three-carbon molecules of pyruvic acid. The term "respiration" refers to the oxidation of pyruvic acid. Fats and proteins are broken up into molecules of pyruvic acid, not glucose, when they are used for respiration.

We believe that the ideas above are too complex for most middle school students. The presentation in this text also has the advantage of making the symmetry between respiration and photosynthesis clear.

The energy on the right side of the equation is not actually created by respiration. Respiration makes chemical potential energy in glucose available for use by the cell.

Although all plants and animals depend on respiration as described in this chapter, there are single-celled organisms, including yeast and anaerolic bacteria, which can obtain energy from food without using oxygen.

Students should recognize that oxygen is one of the substances that is used up during respiration and that this process is taking place in every cell.

Where does the carbon dioxide that you breathe out come from? (Think about what happens during cellular respiration). _____

_____

_____

Another way of describing respiration: The life of a cell

Let's think about a single cell, one of your brain cells, for instance. Your brain cell needs energy to think about reading this page. How will it get that energy? As you read the passage below, use the underlined words to label the arrows on the picture.

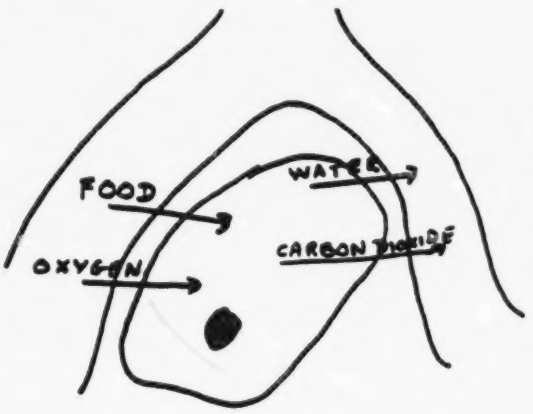
At first the energy that the cell needs is stored in food, and that food is dissolved in the blood. The blood also has something else that the cell needs to get energy from the food, oxygen.

The cell gets food and oxygen from the blood and combines them to release the energy it needs. Now you can read this page! In the process, the food and oxygen are broken down into carbon dioxide and water. This process is cellular respiration.

Now the cell has the energy it needs, but it also has other waste products that it doesn't need: carbon dioxide and water. How can it get rid of those waste products? Give them back to the blood, of course!

Students should recognize that every cell is constantly producing carbon dioxide as a waste product of respiration.

This section reiterates the key ideas of the chapter, emphasizing that the individual cell is the site for respiration.



This is an appropriate point to use Transparency 8.

What happens to the products of respiration?

All of the products of cellular respiration eventually leave the body. Blood carries carbon dioxide to the lungs, where it goes back into the air that you breathe out. Some of the waste water also leaves that way. Water also leaves the body in perspiration and in urine.

The energy released from food by respiration is used by the cells for many purposes: moving, thinking, talking, digesting food, and so forth. Eventually, though, almost all of that energy is converted into heat and leaves your body when you lose heat to the air. Your body heat is a product of cellular respiration!

Using what you have learned about respiration

Let's summarize what we have said about respiration in this chapter:

1. Cellular respiration is the process in which cells get energy by combining food and oxygen.
2. The equation for respiration is as follows:
   glucose + oxygen ------> carbon dioxide + water + energy
3. Our bodies eventually get rid of all of the products of respiration. We breathe out carbon dioxide. Water leaves our bodies as urine, as perspiration, or as water vapor in the air we breathe out. We use the energy, then it leaves our bodies as heat.

Try using these ideas to answer the questions below.

1. Lots of people misunderstand what happens to oxygen in the body. They think that oxygen is taken into the lungs only and that it is changed into carbon dioxide there and then let out of the lungs to the air. Explain what really happens to oxygen. _____

_____

_____

This is an appropriate place to use Transparencies 1-6.

Students should be using these key ideas to answer the questions on this and the next page.

This question asks students to contrast the misconception that breathing involves only the lungs with the biological understanding that breathing is one part of the process of delivering oxygen to every body cell.

Explain where the carbon dioxide really comes from. _____

_____

_____

_____

2. Why are dead people cold? _____

_____

_____

3. If we stop eating, our cells can still get energy by using food stored in our bodies. Do we have lots of oxygen stored in our bodies, too? _____

How do you know? _____

_____

_____

This question asks students to contradict a common misconception about the source of carbon dioxide by stating that it is produced in every cell of the body. Transparency 9 is relevent to this question.

2. This question focuses on the energy transformation in respiration; we continue to produce body heat only as long as respiration continues in our cells.

3. Students can answer this question by contrasting the amount of time that we can live without food (weeks or months) with the amount of time we can live without oxygen (only minutes). We have little capacity for storing oxygen in our bodies.

Now that you've learned about cellular respiration, you should have better answers for the questions you were asked at the beginning of this unit. Look back at the questions you answered on page 11. Have your answers changed? Explain how your new answers to these questions are different from the ones you gave before you started this unit.

1. How do our bodies get the energy we need? _____

_____

_____

2. What happens to the food we eat? _____

_____

_____

_____

3. What happens to the air we breathe in? _____

_____

_____

_____

4. What is respiration? _____

_____

_____

Students should now be able to give functional explanations in response to the questions asked at the beginning of the unit. It should be clear to them that they think about and answer these questions quite differently from the way they did at the beginning of the unit.

If you wish, you can conclude your use of this text at this point. The final chapter, which focuses on organisms other than humans, is not essential for understanding the concepts in the rest of the unit.

CHAPTER VI

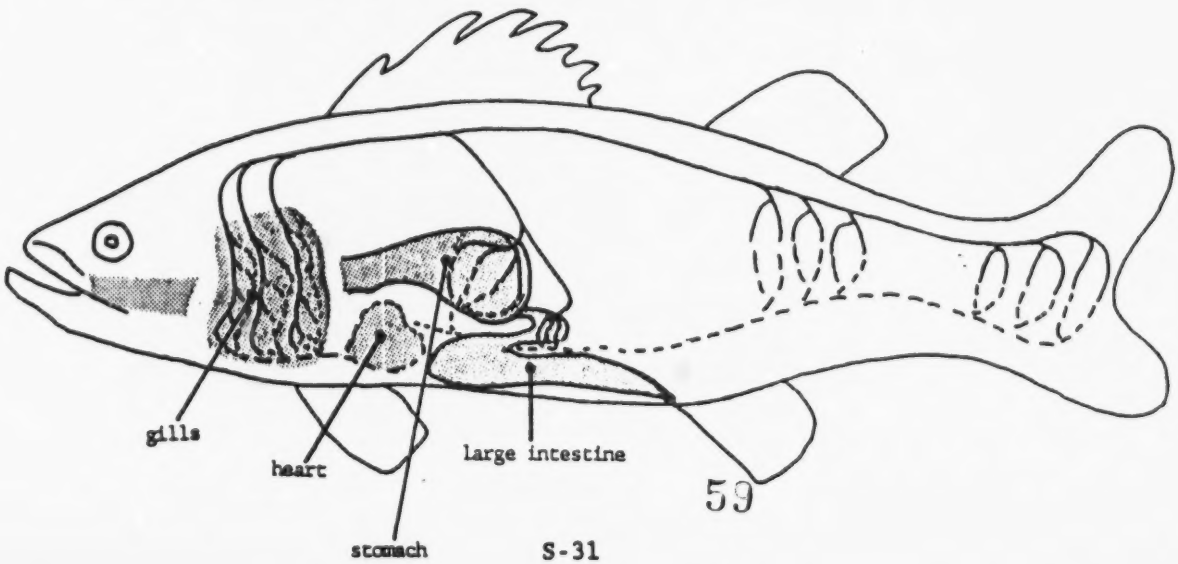
RESPIRATION AND OTHER LIVING THINGS.

So far in this unit we have talked mostly about respiration in people: We get our energy because our cells are constantly combining food and oxygen. What you have learned, though, also applies to other living things. All plant and animal cells get their energy in the same way: The process of respiration!

Respiration in a fish

Let's talk about a different animal as an example: a fish. Fish are like us in that their cells get energy through the process of respiration. Fish also get food to their cells about the same way as we do. They eat, and the food goes to their stomachs, then their intestines. There the useful parts of what they eat enter the blood and the useless parts pass out of their bodies.

Fish don't breathe air, though, so how can they get oxygen? The answer is that they get oxygen from the water. Most water contains dissolved oxygen. Fish take the water in through their mouths. From there it goes to their gills where oxygen passes from the water into the fish's blood. The water then goes out of the fish through gill slits on the fish's side.



This chapter is optional. It considers respiration in another animal (a fish), the relation between respiration and photosynthesis, and how each process occurs in plants.

How do the cells in a fish get their energy? _____

_____

How does food reach the cells in a fish's tail? _____

_____

_____

_____

How does oxygen reach the cells in a fish's tail? _____

_____

_____

_____

Sometimes bacteria or algae in a lake multiply so rapidly that they use up all the oxygen dissolved in the water. What happens to the fish in those lakes? _____

Why? _____

_____

_____

Do you think we will ever discover an animal that has no way of getting food and oxygen to its cells? _____ Explain your answer. _____

_____

_____

Students should see that the answers to the first two questions are exactly the same for fish as they are for humans. The answer for the third question is different for fish and humans in that gills are substituted for lungs.

The best answers to this question are functional in nature. The fish die not just because they have no oxygen, but because their cells are unable to obtain energy through respiration.

The best answers to this question will focus on cell functioning. All animal cells depend for their energy on cellular respiration, so they all must have food and oxygen.

Transparency 7 illustrates the flow of substances in a fish. It can be used at this point.

Respiration and photosynthesis

Have you ever studied the process of photosynthesis? If you have, then you should know what happens to the carbon dioxide and water after they leave your body. They eventually find their way to the leaves of green plants, where photosynthesis takes place. This is the equation for photosynthesis:

carbon dioxide + water + sunlight ----------> glucose + oxygen

This equation means that carbon dioxide, water, and sunlight react and combine to change into glucose and oxygen.

Look carefully at the equation for photosynthesis and the equation for respiration (p. 26). In what ways are they alike? _____

_____

_____

In what ways are they different? _____

_____

_____

Transparencies 10, 11, and 12 all refer to the relationship between photosynthesis and respiration. They can be used in association with this section.

Students should see how matter is constantly recycled in respiration and photosynthesis. The products of one are the reactants of the other. Energy, however, is <u>not</u> recycled. It is converted from sunlight to energy stored in food to energy used by cells, and ultimately to heat.

Question	Answer for photosynthesis	Answer for respiration
Where does this process take place?		
How is <u>matter</u> changed in this process?	Carbon dioxide + water changes to:	glucose + oxygen changes to:
How is <u>energy</u> changed in this process?		

Do you think respiration occurs in plants? Explain your answer. _____

Now let's see if you can summarize what you know about respiration and photosynthesis by filling in the chart below.

Question	Answer for photosynthesis	Answer for respiration
Where does this process take place?	*Some cells (or leaf cells) in plants*	*All plant and animal cells*
How is <u>matter</u> changed in this process?	Carbon dioxide + water changes to: *glucose and oxygen*	glucose + oxygen changes to: *carbon dioxide and water*
How is <u>energy</u> changed in this process?	*Sunlight changes to energy stored in food*	*Energy stored in food changes to energy for cell processes*

Students should realize that respiration as well as photosynthesis occurs in plants. Plant cells need energy as animal cells do, and they depend on respiration to make that energy available.

All plants and animals respire

So far in our discussion of respiration, we have talked mostly about respiration occuring in people and animals. But respiration is necessary for every living cell. This includes plant cells.

People frequently get confused about this. They think that people and plants are opposites: People breathe in oxygen for respiration and plants breathe in carbon dioxide for photosynthesis. This is not the whole story! Plants also take in and use oxygen. They use this oxygen in each of their cells to combine with food to release energy. Thus, plants respire just like other living things. Respiration in plant cells is the same as respiration in animal cells. Oxygen and food are combined and energy, carbon dioxide, and water are produced.

Think about what you know about photosynthesis. Where does the food used by plant cells during respiration come from? _____

_____

When a plant cell respires, what products are given off by the cell? _____

_____

Plants do not walk around or talk. Why do they need energy released in each of their cells during respiration? _____

_____

_____

It is not true that all living organisms respire. All multicellular organisms respire, including animals, plants, and fungi. Anaerobic single-celled organisms such as yeast and some bacteria, however, can survive without oxygen. They extract energy from food by various fermentation processes.

This paragraph contrasts the common misconception that plants are the "opposites" of animals with the more complex truth.

Students should realize (a) that plant cells use food produced in leaves during photosynthesis, not food that the plants take in, (b) that respiration in plant cells yields the same products as respiration in animal cells, oxygen, and carbon dioxide, and (c) that cells have many functions that do not involve movement, such as growth, changing food from one form to another, or maintaining circulation in the plant. All of these processes require energy.

Summarize what you've learned about how plants and animals use the gases they take in by filling in the following chart:

	Gases Taken In	Gases Used In Cells	Processes Gases Are Used For
Plants			
Animals			

We get maple sugar and maple syrup from the sap of maple trees. Why do you think that maple trees have sugar in their sap? _____

_____

_____

Trees that lose their leaves in the fall can't make any food until they grow new leaves. How do you think they keep their cells alive all winter? ____

_____

_____

	Gases Taken In	Gases Used In Cells	Processes Gases Are Used For
Plants	*Oxygen and carbon dioxide (and other gases in air)*	*Oxygen and carbon dioxide*	*Respiration and photosynthesis*
Animals	*Oxygen (and other gases in air)*	*Oxygen*	*Respiration*

Maple sugar is food stored by the tree for its cells to use during respiration.

All plants that survive the winter have some means of storing food for their cells. Examples include maple sugar, potatoes, or onions.

III. OVERHEAD TRANSPARENCIES

This series of overhead transparencies provides opportunities for students to use many of the new concepts that they have learned. They focus students' attention on most of the important issues discussed in the introduction. Class discussions accompanying the use of these transparencies should permit students opportunities to explain and use scientific reasoning about food, energy, and respiration.

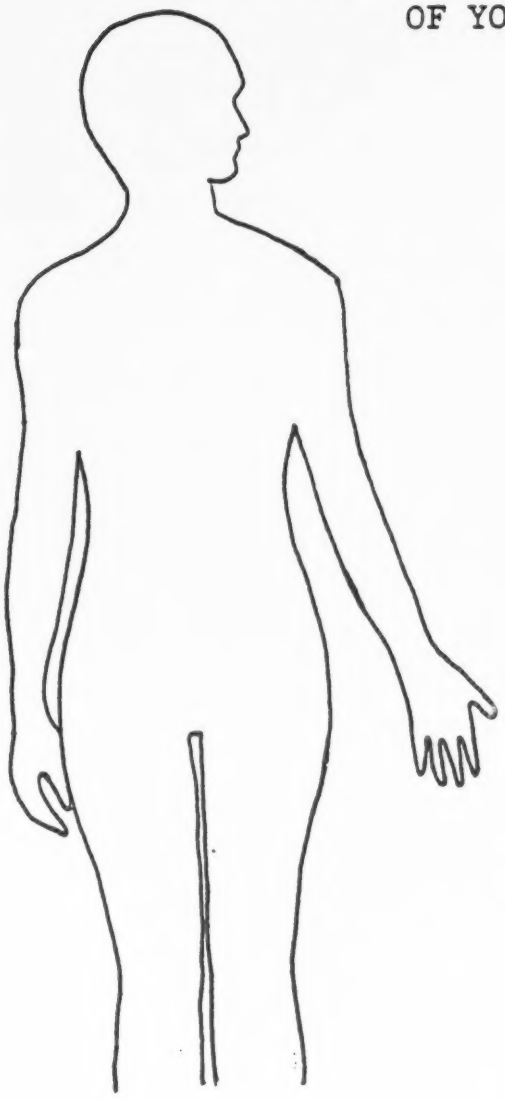
Each of the transparencies poses a question for students to answer. During class discussion, you can elicit student responses to each question from a number of different students. Their answers will reflect whether they are using scientific conceptions or whether they are continuing to rely on naive ways of thinking.

After a number of students have responded to a question, add the appropriate overly to give the scientific answer. For students who answered the question incorrectly, this overlay will provide immediate feedback to them about ways in which their thinking does not match scientific ways of thinking about respiration. Make sure that students notice any differences between their answers and the answers on the overlays. Also help students who give correct answers to recognize how the scientific conceptions are different from what they used to believe.

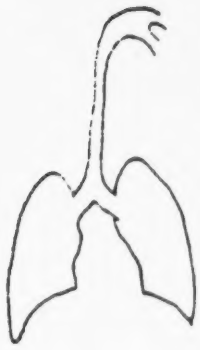
Transparencies 1-6 help students trace the flow of oxygen, food, carbon dioxide and water through the body, to the cells where respiration occurs. Many students are already familiar with movement of oxygen to the lungs, food to the stomach, waste and waste water to feces and urine. But they need to understand that food and oxygen travel beyond the lungs and stomach to every cell of the body, where they are combined to release stored energy for various body functions.

A common student naive conception is that we breathe air into our lungs and take food into our bodies in order to live. The scientific conception of cellular respiration is that food and oxygen function together in cells to release energy. Tracing the paths of these substances may help reinforce that they travel beyond the lungs and stomach to cells.

HOW DOES OXYGEN REACH THE CELLS OF YOUR BRAIN?



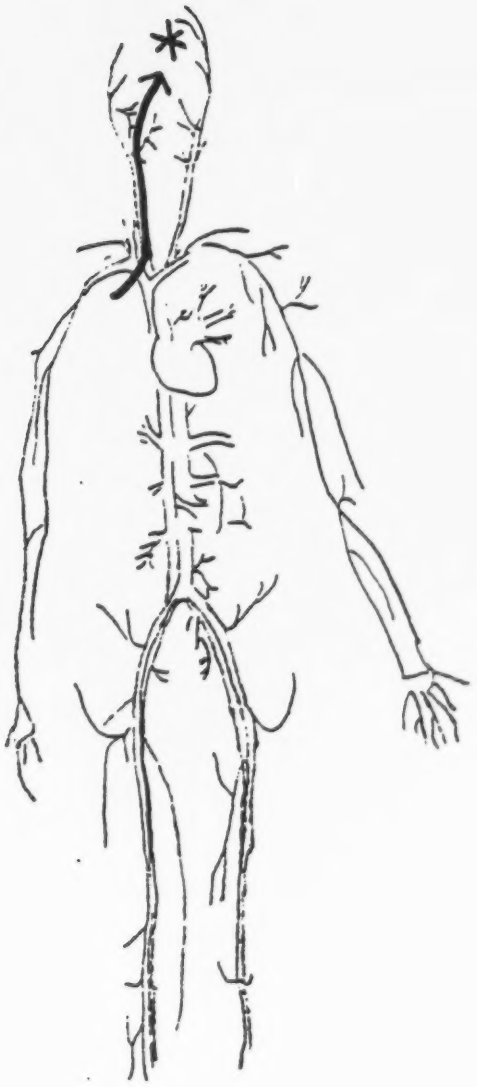
Transparency 1A



AIR IS BREATHED INTO LUNGS.

THEN WHAT?

Transparency 1B

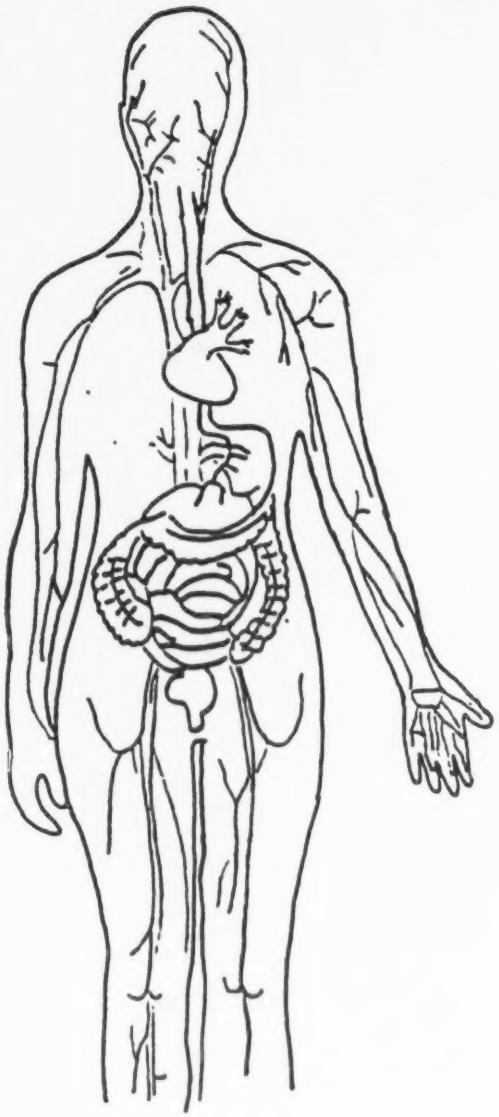


OXYGEN PASSES INTO BLOOD VESSELS,
AND TRAVELS IN YOUR BLOOD TO CELLS IN YOUR BRAIN.

Transparency 1C

HOW DOES FOOD REACH THE CELLS

IN YOUR BRAIN?



Transparency 2A

1 YOU CHEW UP AND SWALLOW FOOD

2 FOOD GOES TO YOUR STOMACH AND SMALL INTESTINE

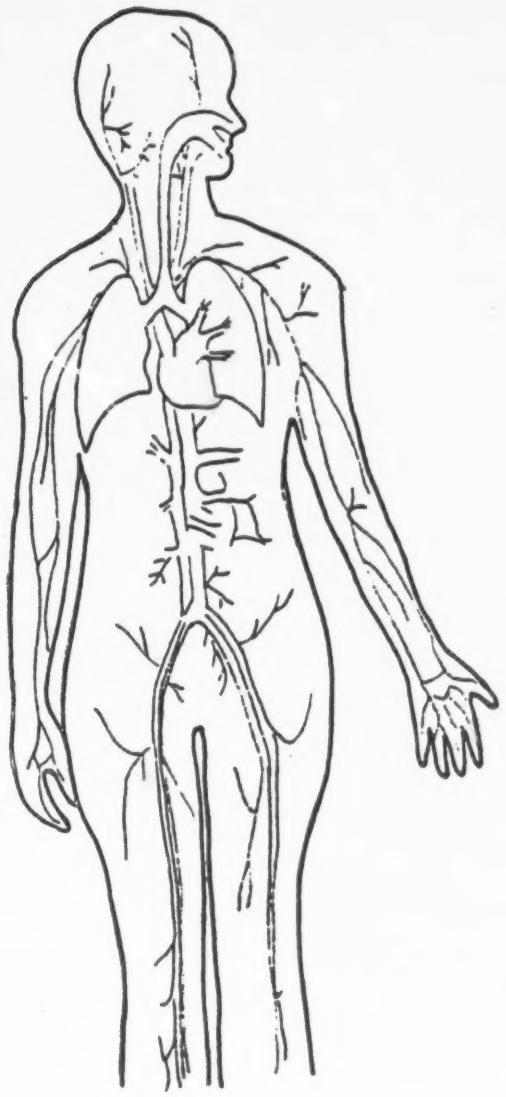
3 ENERGY-CONTAINING FOOD GOES INTO BLOOD AND TO YOUR BRAIN

4 USELESS MATERIALS LEAVE YOUR BODY AS FECES

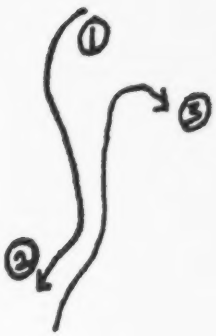
Transparency 2B

WHAT HAPPENS TO <u>CARBON DIOXIDE</u>

FROM RESPIRATION IN YOUR BRAIN CELLS?



Transparency 3A

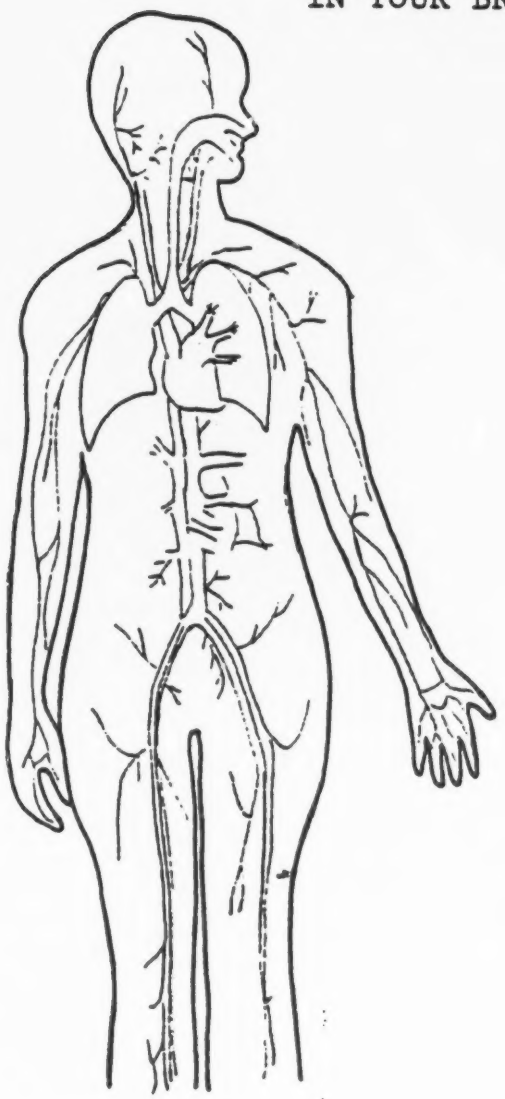


1 CARBON DIOXIDE ENTERS BLOOD IN YOUR BRAIN

2 BLOOD CARRIES IT TO YOUR LUNGS

3 CARBON DIOXIDE GOES INTO THE AIR THAT YOU BREATHE OUT

WHAT HAPPENS TO <u>WATER</u> FROM RESPIRATION IN YOUR BRAIN CELLS?



Transparency 4A

1 WATER ENTERS YOUR BLOOD

2 SOME WATER GOES TO YOUR LUNGS AND LEAVES IN YOUR BREATH

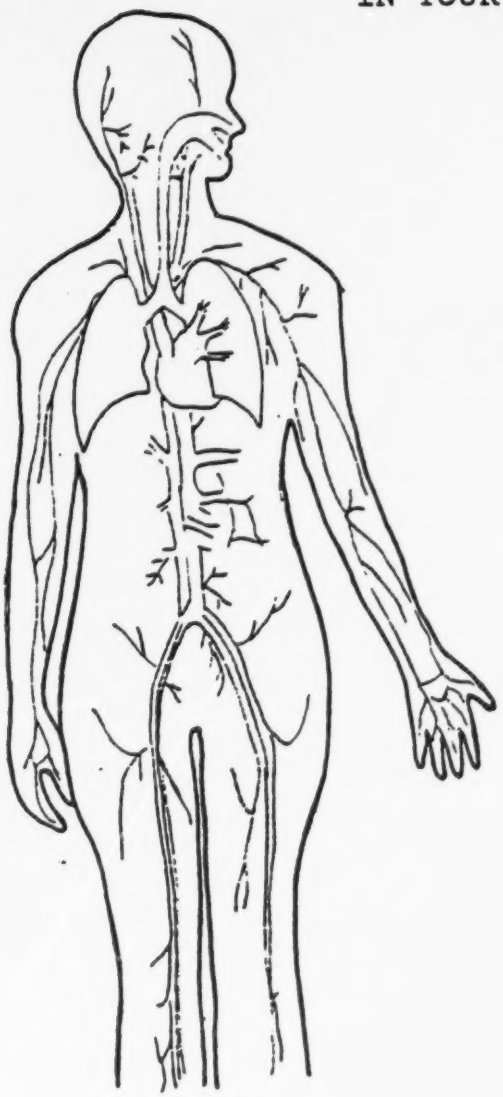
3 SOME WATER GOES TO YOUR KIDNEYS AND LEAVES IN YOUR URINE

4 SOME WATER GOES TO YOUR SKIN AND LEAVES IN PERSPIRATION

Transparency 4B

WHAT HAPPENS TO ENERGY FROM RESPIRATION

IN YOUR BRAIN CELLS?



Transparency 5A

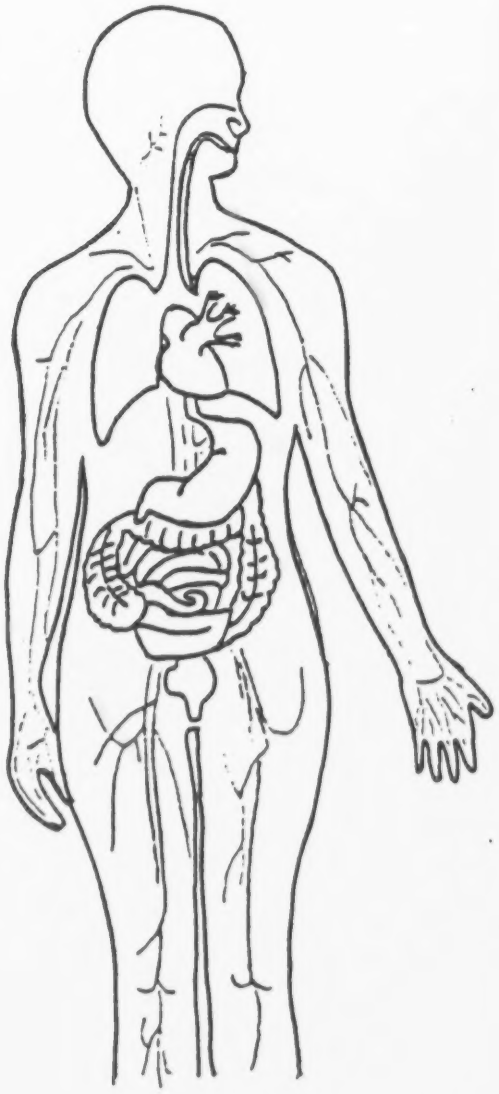
1 ENERGY IS USED BY CELLS AND EVENTUALLY BECOMES HEAT ENERGY

2 HEAT ENERGY LEAVES THROUGH YOUR SKIN

Transparency 5B

PUTTING IT ALL TOGETHER

HOW DO YOUR BRAIN CELLS GET THE ENERGY THEY NEED?



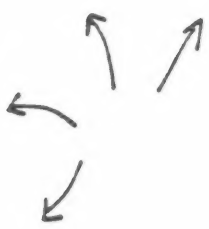
Transparency 6A

FOOD AND OXYGEN TRAVEL TO THE CELL

Transparency 6B

CARBON DIOXIDE AND WATER TRAVEL
OUT OF THE BODY

Transparency 6C



ENERGY IS USED BY THE BRAIN CELLS
AND EVENTUALLY RELEASED FROM YOUR
HEAD AS HEAT

Transparency 7 illustrates cellular respiration in a fish, emphasizing that all animals (and plants) undergo cellular respiration--not just humans. It also reinforces the idea that food and oxygen travel to cells, where stored food energy is released for use by the cell.

Transparency 8 concentrates student attention on the substances necessary for respiration and produced by respiration. It is the only transparency that shows the microscopic view of respiration.

Transparency 9: A common student naive conception is that oxygen is breathed into the lungs and simply transformed into carbon dioxide. This transparency allows you to let students voice this naive conception, then contrast it to the scientific conception that carbon dioxide is a product of cellular respiration.

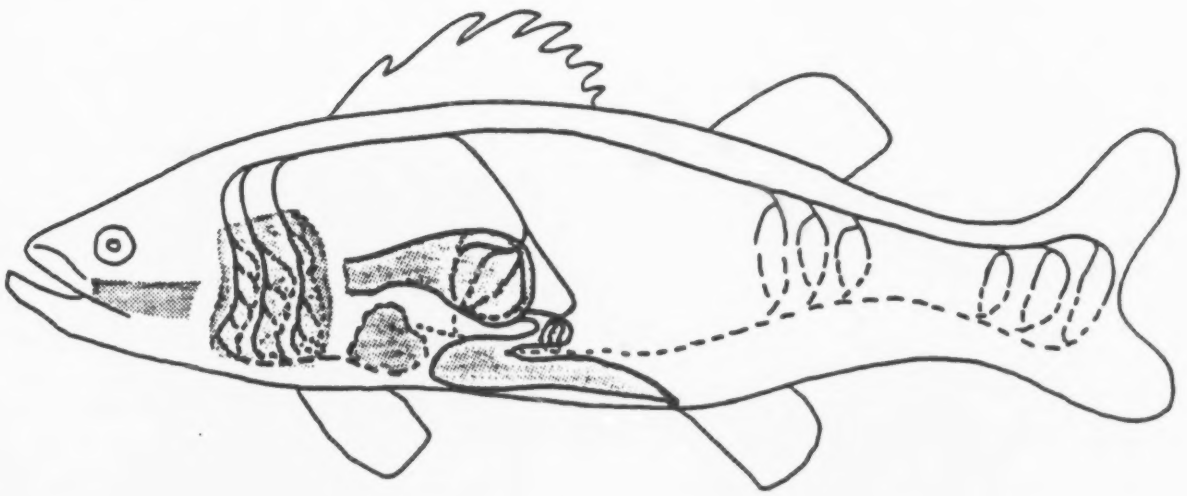
Transparency 10: A common student misunderstanding about one relationship between plants and animals is that animals produce carbon dioxide for plants to use, and plants produce oxygen for animals to use. This transparency shows that oxygen is used in respiration along with food, and carbon dioxide is used in photosynthesis along with water. You should clearly contrast this scientific relationship with the naive relationship about oxygen and carbon dioxide. This is also a good opportunity to point out that cellular respiration occurs in both plants and animals.

Transparency 11: The idea that energy is transformed through photosynthesis and respiration is a very difficult one for most students. In addition, they are often confused about energy being stored in glucose, but sunlight being energy itself.

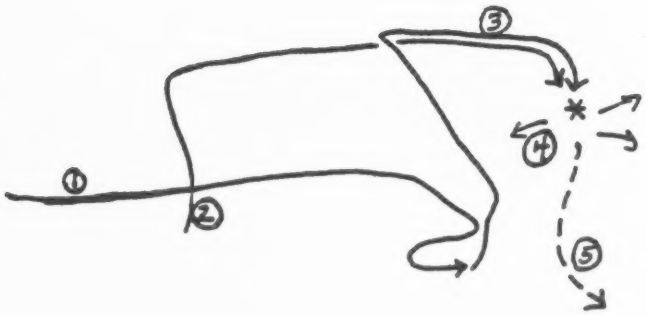
Transparency 12: Students who think of respiration as breathing do not recognize that cellular respiration occurs in plants as well as in animals, and that the food that plants produce is for their own use as well as for consumption by animals. You should emphasize that respiration in plants is the same process as respiration in animals.

This transparency also provides an opportunity to trace the flow of food and oxygen in plant cells. You may also want to trace the flow of carbon dioxide and water out of the plant, and illustrate the ways that plants use the energy released in respiration.

HOW DOES A FISH GET THE ENERGY
IT NEEDS FOR ALL OF ITS CELLS?



Transparency 7A



1 FOOD ENTERS ITS MOUTH AND MOVES TO ITS STOMACH AND INTESTINE

2 OXYGEN IS REMOVED FROM WATER IN ITS GILLS

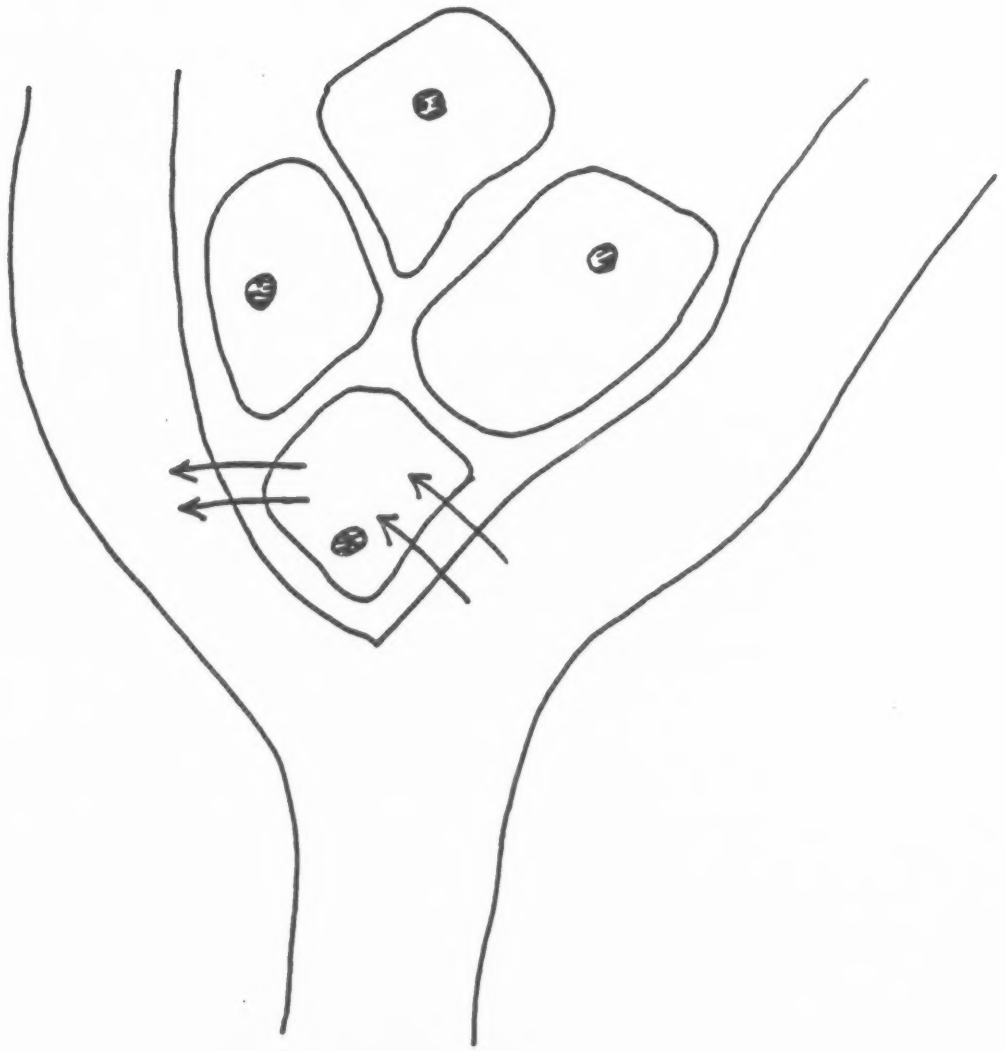
3 FOOD AND OXYGEN TRAVEL THROUGH ITS BLOOD TO ITS CELLS

4 ENERGY IS RELEASED DURING RESPIRATION FOR USE BY THE CELLS

5 WASTES FROM RESPIRATION -- CARBON DIOXIDE AND WATER -- TRAVEL OUT OF ITS BODY

Transparency 7B

WHAT SUBSTANCES GO INTO A CELL
THAT ARE USED TO PRODUCE ENERGY?



Transparency 8A

food

oxygen

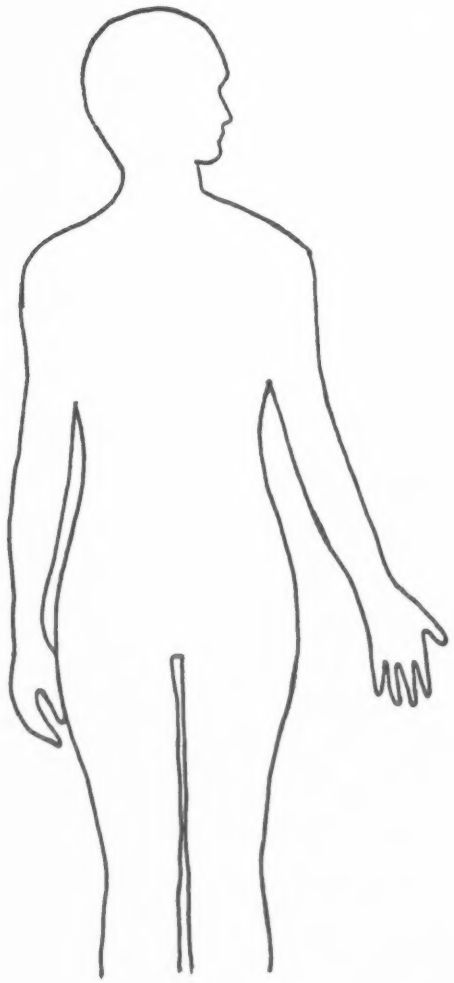
WHAT WASTE SUBSTANCES GO OUT OF A CELL
AS A RESULT OF RESPIRATION?

carbon dioxide

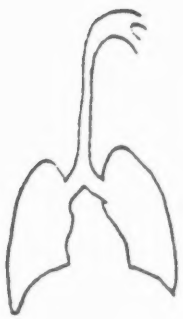
water

Tranparency 8C

WHERE DOES THE CARBON DIOXIDE
COME FROM THAT YOU BREATHE OUT?



Transparency 9A



IS CARBON DIOXIDE PRODUCED IN THE LUNGS?

Transparency 9B

NO!

1 CARBON DIOXIDE IS PRODUCED IN EACH BODY CELL DURING RESPIRATION. THE CARBON DIOXIDE THEN TRAVELS THROUGH THE BLOOD TO THE LUNGS,

2 THEN OUT THROUGH THE MOUTH OR NOSE

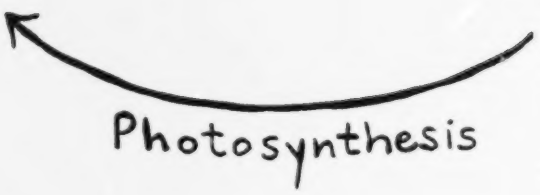
Transparency 9C

RESPIRATION RELEASES ENERGY IN FOOD
BY CHANGING GLUCOSE AND OXYGEN
TO CARBON DIOXIDE AND WATER

GLUCOSE + OXYGEN → CARBON DIOXIDE + WATER

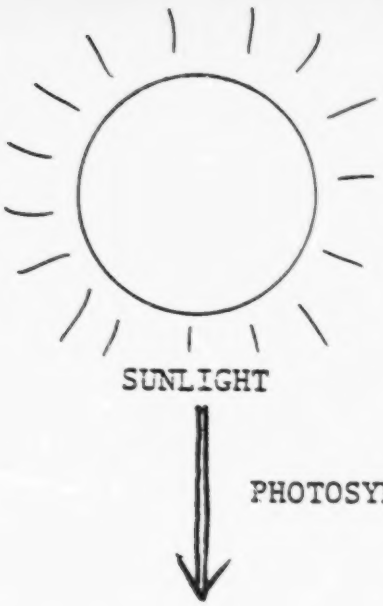
WHAT PROCESS STORES ENERGY IN FOOD
BY COMBINING CARBON DIOXIDE AND WATER
TO FORM GLUCOSE AND OXYGEN?

Transparency 10A



Transparency 10B

HOW IS ENERGY CHANGED
DURING PHOTOSYNTHESIS?



Transparency 11A

HOW IS ENERGY CHANGED DURING RESPIRATION?

FOOD ENERGY IN GLUCOSE

RESPIRATION

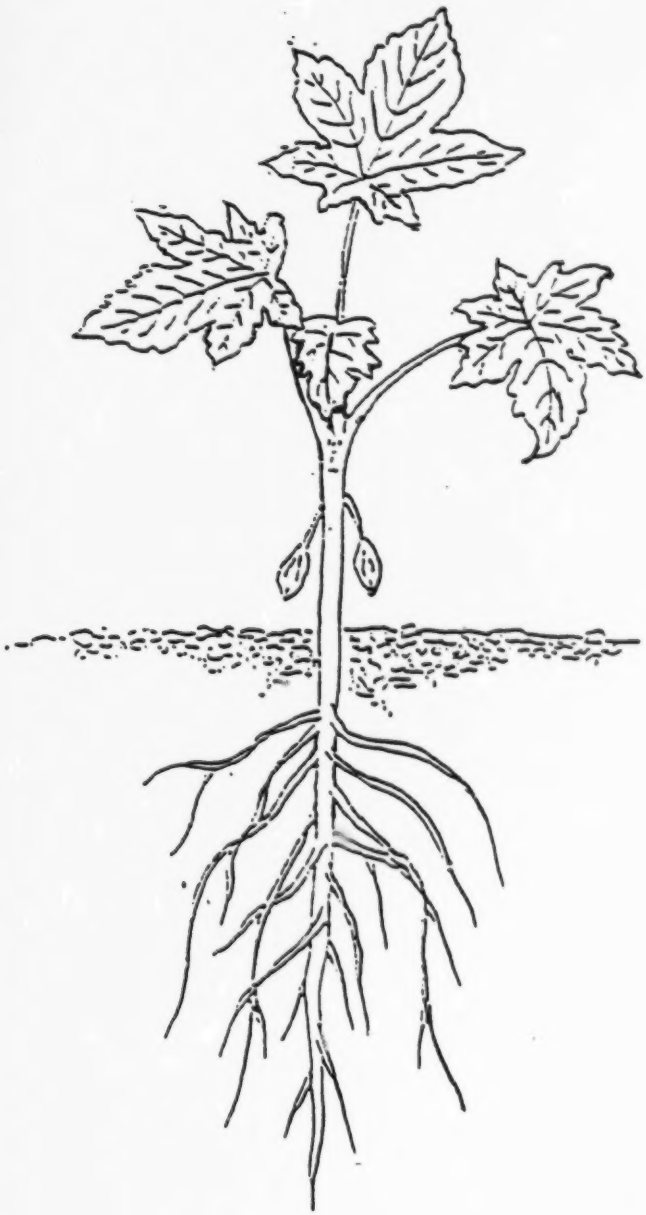
Transparency 11B

ENERGY USED BY CELLS

Transparency 11C

1 HOW DOES OXYGEN GET TO A CELL IN A ROOT?

2 HOW DOES FOOD GET TO A CELL IN A ROOT?



Transparency 12A

1 OXYGEN FROM THE SOIL ENTERS THE ROOT AND PASSES TO THE CELL

2 FOOD PRODUCED IN LEAVES TRAVELS TO THE CELL

WHAT HAPPENS TO THE FOOD WHEN IT REACHES THE ROOT CELL?

Transparency 12B

RESPIRATION!

ENERGY IN THE FOOD IS RELEASED FOR USE
BY THE CELL

Transparency 12C

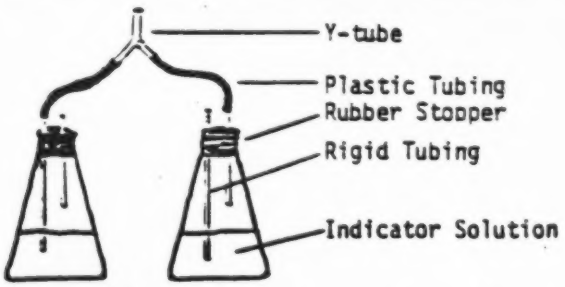
IV. DEMONSTRATION AND LABORATORY ACTIVITIES

Demonstration

Does Exhaled Air Contain More Carbon Dioxide Than Inhaled Air?

This demonstration will help you think about what happens to the air that humans breathe.

Before you watch the demonstration, answer the following question: Do you think that the air you breathe out contains more carbon dioxide than the air you breathe in? Explain.



The two flasks contain a liquid that changes from blue to yellow when large amounts of carbon dioxide pass through it. When someone breathes through the plastic tube, the air going into the lungs will bubble through one flask. The air that is leaving the lungs will bubble through the other flask. Your teacher will show you how the demonstration works. You should carefully observe the color of the liquid in each flask to see if one changes color as air passes through it.

Questions:

1. What happened to the color of the liquid in each beaker?

2. Compare the amount of carbon dioxide in the air that was exhaled to the amount of carbon dioxide in the air that was inhaled.

3. Where was the extra carbon dioxide actually created?

4. What substances were used to make the carbon dioxide.

Does Exhaled Air Contain More Carbon Dioxide Than Inhaled Air?

Introduction: This demonstration is designed to illustrate that the air humans exhale contains more carbon dioxide than air that is inhaled. The students will observe that air which has left the lungs causes an indicator solution to change color, while air that has not yet entered the lungs does not cause a color change. Using information that they are given about the nature of the indicator solution, the students should infer that the color change occurs because the exhaled air contains more carbon dioxide than the inhaled air. Questions at the end of the demonstration relate the presence of CO_2 in exhaled air to cellular processes in which the CO_2 is created.

Materials:

1. BTB (bromthymol blue) indicator solution
2. NaOH Solution (0.1M)
3. Inhaling-Exhaling apparatus
4. Straws
5. Distilled or deionized water

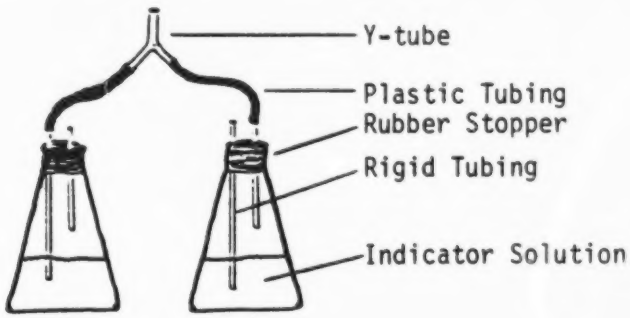
Advance Preparation:

1. 0.1M NaOH: Dissolve 0.4 grams of NaOH in 100 ml water.

2. Demonstration Solution: Add 12-15 drops of BTB (or enough to make a bright blue solution) solution to 500 ml water.

3. Test the solution to determine how much time is required for it to change colors. Put 50 ml of the demonstration solution into a clear beaker. Repeatedly exhale through a straw into the solution (DO NOT INHALE!!). If less than about 20 seconds is required for the solution to completely change color from blue to yellow, add one drop of NaOH to the original demonstration solution, stir, and retest. If more than about 40 seconds are required, dilute the original demonstration solution with 30 ml of water and retest.

4. Construct the apparatus as shown in the diagram below. Add 150 ml of demonstration solution to each beaker.



Place the flasks on a white surface or use a white background to make the solution colors easier for students to see.

5. How did the carbon dioxide get into the air that was exhaled?

6. Rewrite each statement below to make it more complete or correct.

   a. The oxygen you breathe is changed into carbon dioxide and exhaled.

   b. Oxygen goes into the lungs and carbon dioxide comes out.

7. Look back at the explanation you wrote at the beginning of the demonstration. How could you change your explanation to make it better?

Comments

150 ml of demonstration solution may require several minutes of continuous breathing to cause a complete color change from blue to yellow.

You may want to breathe through the tube a few times to let the students see which flask receives inhaled air and which flask receives exhaled air.

There is little possibility of ingesting any of the demonstration solution. The solution is not dangerous, but it will stain skin and clothing.

Answer to Questions

1. The liquid in the beaker receiving exhaled air changes from blue to green to yellow, while the flask receiving inhaled air does not change color.

2. Exhaled air contains more CO_2 than inhaled air. Note that it is incorrect to conclude that the exhaled gas is only CO_2. It is also incorrect to conclude that when people breathe, oxygen is changed to CO_2.

3. The CO_2 was created by the process of respiration in all the living cells, rather than just in the lungs.

4. The CO_2 was created from food (glucose) and O_2 as a waste product during cellular respiration.

5. The CO_2 produced in the cells was carried to the lungs by the circulatory system.

6. These statements reflect students' common misconceptions that breathing involves direct conversion of oxygen into carbon dioxide and that gases only travel to and from the lungs. If the students have understood the concepts about respiration, they should be able to describe how food must be combined with oxygen to create carbon dioxide. Oxygen is transported to all living cells by the circulatory system. Carbon dioxide is produced in the living cells and is then transported back to the lungs through the circulatory system.

7. This question provides students with an opportunity to think about how their ideas about respiration have changed. After seeing the demonstration and discussing the questions, they should be able to describe how the additional carbon dioxide present in exhaled air was produced from food and oxygen.

Laboratory Activity

EXERCISE, ENERGY NEEDS, AND CELLULAR RESPIRATION

Introduction. This laboratory exercise illustrates the effects of exercise on the processes that supply cells with energy. The students will observe that exercise increases the amount of CO_2 in exhaled air, and that breathing and pulse rates are increased. They will infer that exercise increases cells' energy requirements, resulting in increased rates of cellular respiration. The increased rate of cellular respiration requires that breathing and pulse rates increase in order to supply the cells with food and oxygen and to remove waste products.

Materials:

BTB (bromthymol blue) indicator solution

0.1M NaOH solution

150 ml flasks or beakers--2 per lab group

straws--4 per lab group

distilled or deionized water

timers or a clock with a second hand

Advance Preparation:

1. 0.1M NaOH: Dissolve 0.4 grams of NaOH in 100 ml of water.

2. Student Test Solution: Each lab group will require about 200 ml of solution. Three liters should be sufficient for a class of 25 students. Use enough BTB indicator to make a bright blue solution.

3. Test the Solution to determine how much time is required for it to change color. Put 50 ml of solution into a clean beaker. Exhale through a straw into the solution, noting the time required for it to change completely from blue to yellow. If less than about 20 seconds is required, add 2-3 drops of 0.1 M NaOH to the original solution and retest. If more than about 40 seconds is required, dilute the original solution with 30 ml of water and retest.

EXERCISE, ENERGY NEEDS, AND RESPIRATION

Introduction. This laboratory activity will help you to better understand how respiration supplies your body's cells with the energy they need to live and grow. You have already learned that all living cells combine food and oxygen to get energy. You also know how food and oxygen get to your cells. In this activity, you will see how exercise affects all these processes.

Directions:

1. You should work in teams of two. One person should act as observer and record data while the other person completes the activities. When you finish steps 2-7, switch roles so the other person can do steps 2-7.

2. Count your normal breathing rate and pulse for 30 seconds. Record them in the data chart below.

3. On your table are two small flasks. Put 50 ml of blue test solution in each beaker. This solution will change colors from blue to green to yellow when large amounts of carbon dioxide pass through it.

4. Inhale deeply. Using the straw, blow steadily into the solution in one of the beakers while your partner watches the clock. Repeat until the solution has just turned yellow. NOTE: DO NOT INHALE THROUGH THE STRAW. Record the time it takes for the solution to change color in the chart below.

5. Now exercise by jogging in place for two minutes.

6. Immediately after you stop exercising, inhale deeply and exhale through the straw into the solution in the other beaker. Repeat until the solution just turns yellow. Measure and record the time it takes for the solution to change color.

7. Again, count your pulse and breathing rate for 30 seconds and record below.

	BEFORE EXERCISE	AFTER EXERCISE
Breathing Rate		
Pulse		
Time for Solution to turn Yellow		

Teacher Comments

This laboratory activity is an opportunity for students to apply what they have learned about cellular respiration to explain some of the effects of exercise on the body. Students who have learned important concepts about cellular respiration should recognize that, as the body's demand for energy increases through exercise, respiration will have to occur at a greater rate in order to supply the needed energy. The only way that respiration can increase is if increased quantities of food and oxygen are supplied to the cells.

The BTB solution is not dangerous, but it will stain skin and clothing.

Make sure the students understand that they should exhale only until the solution has turned completely yellow.

Questions:

1. Do muscle cells need more or less energy when you exercise? _____

2. What process do muscle cells use to get the energy they need? _____

3. What substances to muscle cells need in order to respire faster?

   _____ and _____

4. Use the above ideas about muscle cells to explain why exercise changes your breathing rate.

5. Use the above ideas about muscle cells to explain why exercise changes your pulse rate.

6. How did exercise change the time it took for the indicator solution to change from blue to yellow.

7. What does this tell you about the amount of carbon dioxide in the air you exhaled?

8. Where in the body is the additional carbon dioxide produced? _____ _____

9. How would you explain why exercise makes your body produce more carbon dioxide?

Answers to Questions:

1. More

2. Respiration

3. Food and Oxygen

4. The students should be able to relate increased exercise to increased demands for energy. They should understand that cells cannot supply additional energy unless they have more oxygen. Thus, breathing rates increase to supply additional oxygen so that cellular respiration can meet the body's demand for energy.

   Some students may also recognize that increased breathing rates remove carbon dioxide from the body more quickly.

   Students who state that breathing increases "to get oxygen to stay alive" or "to keep from getting tired" are not using functional explanations, and have probably missed the point of the question. They are making statements about the effects of oxygen deprivation while failing to recognize the important metabolic role of oxygen in maintaining life (combining with food to release energy).

5. As the body's energy demands increase, blood circulates faster to supply cells with additional food and oxygen and remove carbon dioxide and other waste products. Students should recognize that the circulatory system is the only way that muscle cells can obtain food and oxygen and get rid of waste products.

6. The students should observe that the indicator solution took less time to change color after exercise.

7. The exhaled air contained more carbon dioxide after exercise than before exercise.

8. Muscle cells

9. Responses should refer to cellular processes. The students should understand that all plant and animal cells respire and produce carbon dioxide. During exercise, however, muscle cells produce additional carbon dioxide as respiration rates increase to meet the demand for more energy. Again, students who fail to refer to cellular processes and energy use don't understand the role of cellular respiration in supplying cells with energy.